THE JOURNAL OF RAPTOR RESEARCH

A QUARTERLY PUBLICATION OF THE RAPTOR RESEARCH FOUNDATION, INC.

VOL. 35 DECEMBER 2001 No. 4

J. Raptor Res. 35(4):269–273

THE SECOND INTERNATIONAL BURROWING OWL SYMPOSIUM: BACKGROUND AND CONTEXT

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This issue of *The Journal of Raptor Research* showcases the proceedings of the Second International Burrowing Owl Symposium, held from 29–30 September 1998 in Ogden, Utah. The symposium was well attended, and the enthusiasm and insights of over 110 participants, mainly from Canada, Mexico, and the United States, brought a higher profile to growing concerns for Burrowing Owl (*Athene cunicularia*) populations and their conservation. Our current knowledge of this species was expanded by presentations on the owls' distribution, the extent of their declines, and new discoveries about the owl's genetics, behavior, and population biology within many states and provinces. We learned about the ecology of owls from as far north as Saskatchewan and as far south as Colombia. Despite the variety of biological disciplines represented, and the diversity of grassland systems with which participants were familiar, they all shared a common interest and concern for the species.

This symposium was a natural follow-up to the First International Burrowing Owl Symposium, organized by Jeff Lincer (Lincer and Steenhof 1997). The first symposium was held in November 1992 in Seattle, Washington, immediately before the Raptor Research Foundation's annual meeting. That symposium originated because of concern about the status of the Burrowing Owl, particularly in California and Canada. Its focus was the biology and management needs of the Burrowing Owl.

After the first symposium, several important events shaped the objectives of the second symposium: the Burrowing Owl's status changed in Canada, an international working session was held, two new international agreements were signed, and the North American Raptor Monitoring Strategy was initiated.

In 1995, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designated the Burrowing Owl as an endangered species. Wellicome and Haug (1995) recommended this designation in light of further retraction of the species' range in Canada (Fig. 1) and the persistence and pervasiveness of the population decline. At annual meetings of the Canadian Burrowing Owl Recovery Team, members shared reports from landowners and researchers that indicated overall population declines in excess of 20% per yr in the three prairie provinces. Biologists documented the disappearance of the owl from former strongholds in Saskatchewan and Alberta (Wedgwood 1978, Haug 1985, Wellicome et al. 1997, Shyry et al. 2001) and its extirpation from the provinces of British Columbia (Leupin and Low 2001) and Manitoba (De Smet 1997, K. De Smet pers. comm.).

In Winnipeg in February 1997, Holroyd and Wellicome (1997) organized a workshop on Burrowing Owl conservation at the Second International Symposium on the Biology and Conservation of Owls of the Northern Hemisphere. At this workshop 85 participants heard the latest reports from various researchers. For example, Bob Murphy described preliminary surveys for Burrowing

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Figure 1. Current and historical ranges of the western Burrowing Owl (*Athene cunicularia hypugaea*) in North America. Current distribution modified from Haug et al. 1993, from North American Breeding Bird Survey distribution map for the Burrowing Owl (Sauer et al. 2001), from individual papers in the Proceedings of the Second International Burrowing Owl Symposium (*J. Raptor Res.* 35[4]), and from personal communications with numerous local experts within each province and state. Historical range (pre-1970s) taken from Zarn (1974), from Wedgwood (1978), and from personal communications with local experts. In states that lacked detailed distributional data, owls were presumed to be absent from areas of forest or rugged mountains. The historical range is unknown for Mexico.

Owls in North Dakota that showed the absence of the owl in areas that it was formerly common, and Dennis Flath estimated that black-tailed prairie dogs (*Cynomys ludovicianus*) had declined by 88% in Montana, presumably accompanied by declines in Burrowing Owl populations. Unfortunately, these alarming trends were apparently not limited to the north, as Lynne Trulio (1997) and Janis Buchanan (1997) reported severe declines of Burrowing Owls in parts of California (see also DeSante et al. 1997). One main recommendation from the Winnipeg workshop was that the status of the Burrowing Owl in western North America be determined through a range-wide, systematic survey. Another recommendation from the workshop was that a second international Burrowing Owl symposium be held.

On 9 April 1996, the 'Canada/Mexico/United States Trilateral Committee for Wildlife and Ecosystem Conservation and Management' was established through an international memorandum of understanding signed by the directors of the federal wildlife agencies of the three countries. The purpose of the agreement was "to facilitate and enhance coordination, cooperation, and the development of partnerships among the wildlife agencies of the three countries, and with other associated and interested entities, regarding projects and programmes for the conservation and management of wildlife, plants, biological diversity and ecosystems of mutual interest .... Such projects and programs include scientific research, law enforcement, sustainable use and any other aspect related to this purpose." At the second meeting of the Trilateral Committee, in February 1997 at Phoenix, Arizona, a working group was established to develop a continental approach to the conservation of Burrowing Owls. One representative from each of the three countries comprised the working group, which shared preliminary correspondence about international cooperation and communication to recover the Burrowing Owl. The Second International Burrowing Owl Symposium was organized by Geoff Holroyd as an activity of this group. Effective international cooperation toward species recovery requires a solid foundation, so one objective of the symposium was to develop a conservation plan for the species in North America.

Another international agreement that could aid Burrowing Owl conservation is the Framework for Cooperation in the Protection and Recovery of Wild Species at Risk, which was signed by the U.S. Fish & Wildlife Service and the Canadian Wildlife Service in April 1997. At the second meeting of the two parties, in June 1998 in Ottawa, the Burrowing Owl was identified as a candidate species for binational action. One of the action items was to "develop work plans for cooperative recovery action for individual species," again highlighting the need for a conservation/recovery action plan for the Burrowing Owl in North America.

Through the course of these meetings and from other communications, it soon became clear that, because the Burrowing Owl was not listed under the U.S. Endangered Species Act, the ability of U.S. federal agencies to expend resources on research and conservation for this species was limited. Thus, another objective of the second symposium was to provide a preliminary indication of the status of the Burrowing Owl in as many jurisdictions as possible in North America.

In August 1996, a workshop was held in Boise, Idaho to discuss a North American raptor monitoring strategy. The goal of this strategy is to develop monitoring approaches for all of the continent's raptors, including owls (Holroyd and Takats 1997). This goal further reinforced the need for discussions about monitoring techniques for the Burrowing Owl.

Executives of the Raptor Research Foundation, Inc. and the local conference organizing committee headed by Carl Marti, graciously agreed to hold the symposium immediately before the 1998 annual meeting. Our immediate managers, Gerald McKeating and Loney Dickson, approved Canadian Wildlife Service (Environment Canada) funds to host the meeting, and World Wildlife Fund Canada provided travel assistance for several speakers.

The overall goal of the Ogden symposium was to determine the status and conservation needs of the Burrowing Owl, its prey, and its habitat. The objectives of the symposium were to:

(1) Determine the status of the Burrowing Owl,
(2) Identify conservation issues that affect Burrowing Owls,
(3) Identify known or likely solutions to these problems,
(4) Identify expertise in fields relevant to Burrowing Owls,
(5) Identify research needs for Burrowing Owl conservation, and
(6) Recommend Burrowing Owl monitoring strategies.

At the symposium, over 110 researchers from Canada, Mexico, the United States, and South America listened to 34 presentations on the Burrowing Owl and its habitats. After the symposium, some authors either did not pursue publication or published their data elsewhere; however, these proceedings include many of the papers presented at the 1998 symposium, along with some additional solicited papers. Articles cover a wide range of topics within the broad categories of biology, status and trends, and conservation and management of Burrowing Owls. These studies span all four provinces and 13 of the 19 U.S. states within the owls' range (Fig. 1), and one paper (Holroyd et al. 2001) includes information on Burrowing Owls in Mexico. In the final plenary working session, there was consensus that Burrowing Owls were declining across much of their range in western North America, and participants drafted an outline for the Burrowing Owl Conservation Action Plan (Holroyd et al. 2001), which later was presented to the Trilateral Committee in 2000.

No date or place has been set for a third Burrowing Owl Symposium, but we suggest that one be held at the 2002 Raptor Research Foundation annual meeting in New Orleans. In the meantime, a new list serve for Burrowing Owl researchers and managers has been created by John Sidle. To subscribe to the Burrowing Owl list serve, type "subscribe burrowingowl *your name*" in the body of an e-mail message, leaving the subject line blank, and send it to "listserv@unl.edu."

As we look to the future, there is much work to be done in Mexico, in both summer and winter. In the western U.S., promising research is already underway in California (D. Rosenberg pers. comm.), Oregon, and Washington (C. Conway pers. comm.), where ground squirrels (Sciurids), rather than prairie dogs (*Cynomys* spp.), are the main burrow providers. We are not aware of any research on Burrowing Owls in Nevada or Utah. Also, Texas is home to a large number of owls in all seasons (James and Espie 1997), and this seems like a promising location for future studies. Perhaps through further investigation where Burrowing Owls are thought to be faring well (for example, in parts of Idaho [J.R. Belthoff and K. Steenhof pers. comm.] or Colorado [Lutz and Plumpton 1997]) we might uncover the keys to healthy populations. We are encouraged by progress in the development of a standardized survey protocol for Burrowing Owls (C. Conway unpubl. data; J. Duxbury unpubl. data), but much fieldwork and coordination remains before a wide-scale survey can be realized.

Although reasons for declines might be intricate and varied, one clear theme that emerged from this symposium was the importance of fossorial mammals to the Burrowing Owl's ecology. It follows then that conservation of prairie dogs, ground squirrels, badgers (*Taxidea taxus*), kangaroo rats (*Dipodomys* spp.), and other burrow-providers is of utmost importance. The 1998 petition to list the black-tailed prairie dog as a Threatened species in the U.S., and ensuing management efforts on that species' behalf, are timely for Burrowing Owls and other wildlife in the Great Plains. Internationally-coordinated, cooperative efforts on Burrowing Owls, in concert with more general conservation programs, holds the greatest promise for long-term protection of the many species that rely on grassland ecosystems on this continent.

ACKNOWLEDGMENTS

The symposium was funded by Environment Canada and World Wildlife Fund Canada (WWFC). WWFC paid for transportation of participants from British Columbia, Mexico, and Colombia, and provided funds through the Beaverhill Bird Observatory to edit and publish the proceedings. Environment Canada funded travel from Alberta, paid for the conference center, and contributed to the publishing costs. Janis Buchanan, Jason Duxbury, Jeff Lincer, Carl Marti, Bob Murphy, Steve Sheffield, John Sidle, Helen Trefry, and Lynne Trulio served on the program committee. We thank Darcey Shyry, Robert Sissons, and Helen Trefry, who served as a local committee for the symposium, and Marco Restani, Ken De Smet, Scott Hutchings, and Brenda Johnson, who completed more than their fair share of manuscript reviews. We appreciate the help of many people, especially Dave Stepnisky, in the creation of Fig. 1. Special thanks to Carl Marti who arranged for the conference center facilities in Ogden, Utah.

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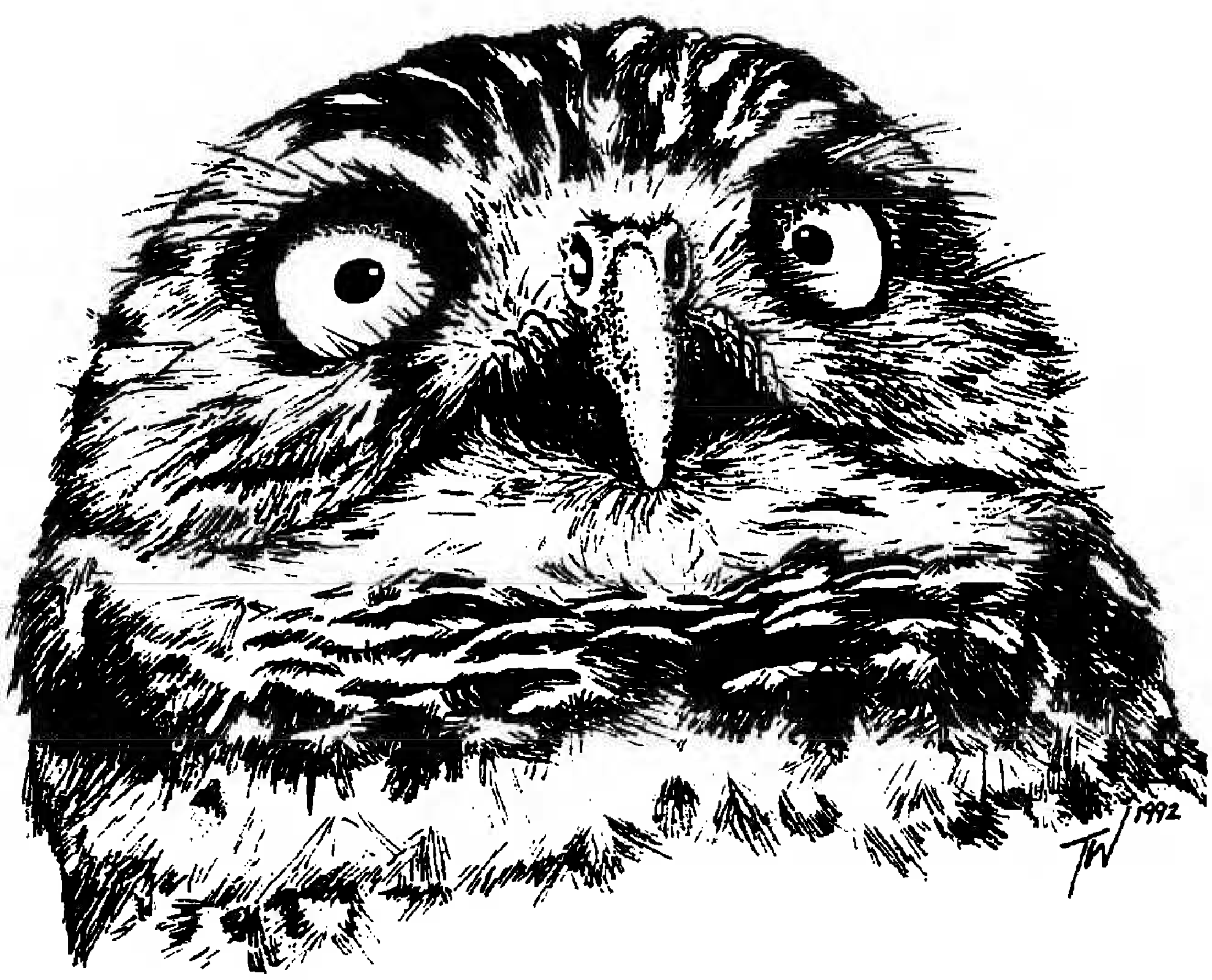

J. Raptor Res. 35(4):274–281

AN INITIAL EXAMINATION OF MITOCHONDRIAL DNA STRUCTURE IN BURROWING OWL POPULATIONS

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ABSTRACT.—Sequence variation was examined in the cytochrome b region of the mitochondrial genome of Burrowing Owls (*Athene cunicularia*) from North and South America, and compared with the Elf Owl (*Micrathene whitneyi*), Barred Owl (*Strix varia*) and Eastern Screech Owl (*Otus asio*). Attempts to clone and sequence the control region of the mitochondrial genome resulted in sequences that appeared to be nuclear copies of that region. Cytochrome b sequences revealed a genetic split between Burrowing Owl populations from North and South America. This split may date back 2 million yr to the connection of these continents via the isthmian land bridge. Additional population structure appears to be of Pleistocene origin or more recent. Data indicate a possible North American origin for Burrowing Owls and subsequent dispersal via the land bridge to the South American continent. The depth of the split between Burrowing Owls from North and South America is consistent with species-level distinction. Additional data from nuclear markers, morphology and/or ecological indicators, such as behavior or vocalizations, will be necessary to confirm these results.

KEY WORDS: *Burrowing Owl*; Athene cunicularia; *mitochondrial DNA*; *cytochrome b*; *genetics*; *North America*; *South America*.

Analisis preliminar de la estructura del adn mitocondrial en poblaciones de Búho Cavador

RESUMEN.—La variación de la secuencia fue examinada en la región del citocromo b del genoma mitocondrial de Búhos Cavadores (*Athene cunicularia*) de Norte y Sur América, y fue comparada con las del Búho Elfo (*Micrathene whitneyi*), el Búho Barreteado (*Strix varia*) y el Búho Chirriador oriental (*Otus asio*). Los intentos para clonar y secuenciar la región de control del genoma mitocondrial dieron como resultado secuencias que parecían ser copias nucleares de esa región. Las secuencias del citocromo b revelaron una división genética entre las poblaciones de Búhos Cavadores de Norte y Sur América. Esta escisión puede datar de 2 millones de años atrás cuando se conectaron estos dos continentes por medio del puente terrestre del istmo. Otra estructura de la población parece tener origen en el Pleistoceno o mas recientemente. Los datos indican un posible origen Norteamericano para el Búho Cavador y una subsecuente dispersión hacia el continente Suramericano a través del istmo. La profundidad de la división entre los Búhos Cavadores de Norte y Sur América es consistente con el nivel de distinción a especie. Datos adicionales a partir de marcadores nucleares, morfología y/o indicadores ecológicos, al igual que comportamiento o vocalizaciones, serán necesarios para confirmar estos resultados.

[Traducción de Victor Vanegas y César Márquez]

The Burrowing Owl (*Athene cunicularia*) is widely distributed throughout the New World, from southern Canada through Argentina, including the West Indies. Suitable habitat includes arid areas, savannas, and grasslands (Pregill and Olson 1981, Johnsgard 1988). Burrowing Owls nest in burrows and, depending on geographic locality, nest in burrow systems of colonial sciurids, other

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burrowing vertebrates, natural cavities, or dig their own burrows. Currently treated as a single species, the Burrowing Owl has 18 recognized subspecies described on the basis of plumage characteristics and geographic variation in size (Peters 1940).

The Burrowing Owl fossil record, although sparse, and the biogeographic history of savanna/arid habitats throughout the New World have led to the development of hypotheses about the evolution of this species. A presumed owl ancestor *Speotyto megalopeza* first appeared in the fossil record in the Pliocene in western Meade County, Kansas, U.S.A. (Ford 1966). The first recorded Burrowing Owl fossil from South America is from the Pleistocene (Vuilleumier 1985). The most extensive fossil record of the Burrowing Owl is found in the West Indies from the Pleistocene (Pregill and Olson 1981). The savanna/arid habitats evolved separately on the North and South American continents during the Cenozoic. For most of this period, the two continents were physically separated and the centers for the evolution for arid land communities were located centrally within each continent (Webb 1977). In North America, the amount of open habitat replacing forests increased substantially throughout the Cenozoic. Today, greater than 25% of the land cover of North America is nonforest (Webb 1977). The full extent of savanna and arid habitats in South America during this same period is not fully understood and remains controversial. Evidence indicates the development of flora associated with open habitats during the early Cenozoic. The presence of open country vertebrates from fossil sites dates to the same period and includes early ungulates, chinchilds, octodontids, and large grassland birds, such as rheas (*Rhea* spp.) and the carnivorous phorusrhacids (Webb 1978). Climatic shifts of alternating humid and dry periods in South America, associated with glacial and interglacial periods, contributed to the disjunct distribution of savannas, grasslands, and other xeric habitats (Haffer 1974). This likely contributed to the disjunct populations of Burrowing Owls currently found throughout the South American continent.

Based on the current disjunct distribution of some owl populations, climatic fluctuations, and evidence of historical extinctions and range reductions of Burrowing Owls in the West Indies, we hypothesized that mitochondrial DNA (mtDNA) would reveal population structure by broad geographic locality. Specifically, we predicted in North America the resident Florida subspecies (*A. c. floridana*) would be genetically distinct from western populations (*A. c. hypugaea*) because of its geographic isolation. We also predicted a genetic break would exist between populations found in North America and South America. Within South America, we anticipated finding genetic differences between broad areas because of the apparent restricted range and isolation of many populations and their presumed resident status.

Methods

To test our hypotheses, samples from five recognized subspecies of Burrowing Owls were analyzed. Blood samples of ≤0.5 cc were collected from the western subspecies (*A. c. hypugaea*) in Nebraska, South Dakota, Oregon, California, and New Mexico. Blood samples of the Florida subspecies (*A. c. floridana*) were collected by Brian Mealy (Univ. Florida-Miami). Tissue samples were obtained from museum tissue collections for Burrowing Owls from Baja California, Mexico (*A. c. hypugaea, N* = 1); Providences Tucaman and Corrientes, Argentina (*A. c. cunicularia, N* = 2); Providence Trujuilo, Peru (*A. c. nanodes, N* = 1); and Providence Loja, Ecuador (*A. c. punensis, N* = 1). The initial analysis for broad geographic variation was conducted on one specimen from each of the widely separated populations from Nebraska, California, New Mexico, Florida, Baja California, Mexico, Argentina (Provinces Tucaman and Corrientes), Peru, and Ecuador to evaluate the potential of the selected marker to identify population structure. Samples were also obtained from the Elf Owl (*Micrathene whitneyi*), Barred Owl (*Strix varia*), and Eastern Screech Owl (*Otus asio*) for comparative purposes.

Target DNA Sequences. Our original objective was to examine two regions of the mitochondrial genome (the control region and a section of the cytochrome b region) to address geographic variation within subspecies, as well as broad-scale variation. However, attempts to use southern blotting to develop specific control region primers to address finer-scale questions resulted in sequences that appear to be nuclear copies of this region (Desmond 1997). These sequences are therefore not discussed further in this paper. Universal cytochrome b primers designed by Kocher et al. (1989) were used to amplify the 297 bp section from the cytochrome b region. Results from these sequences are the focus of this paper.

DNA Extraction. DNA was extracted from blood and tissue by digestion in 100 mM Tris pH 7.5, 100 mM EDTA pH 8.0, 100 mM NaCl, 0.5% SDS, and Proteinase K (0.5 ug/ml) overnight at 55°C. The DNA was purified by extracting once with phenol, chloroform (24:1, chloroform:isamyl alcohol) and twice with chloroform:isamyl alcohol (24:1). Each sample was then ethanol precipitated overnight, pelleted and washed twice with 70% ethanol, dried and re-suspended in a buffer of 1M Tris and 10M EDTA.

Polymerase Chain Reaction (PCR) Amplification. Amplification was performed in 50 ul reactions containing 10 mM Tris-HCl (pH 8.3), 50 mM KCl, 1.5 mM $MgCl_2$, each dNTP at 1mM, each primer at 5 uM, and 2 units of

Table 1. Numbers and percentages (in parentheses) of the four nucleotides in the cytochrome b sequences of the Burrowing Owl, Barred Owl, and Elf Owl, respectively.

	A	C	T	G
Athene cunicularia	71 (24)	106 (36)	70 (24)	49 (17)
Micrathene whitneyi	82 (28)	96 (33)	71 (24)	43 (15)
Strix varia	76 (26)	99 (33)	71 (24)	50 (17)
Otus asio	73 (25)	102 (35)	70 (24)	51 (17)

Taq. Each cycle of the polymerase chain reaction consisted of denaturation at 94°C for 1 min, annealing at 47°C for 1 min, and extension for 1 min 30 sec at 72°C. This cycle was repeated 35 times. All cytochrome b amplifications were sequenced using an automated sequencer at the Iowa State University DNA sequencing facility. Sequence results were checked manually using the program Editview (Version 1.0, Perkin Elmer).

To test against the possibility of contamination, blood samples of Burrowing Owls from Nebraska, Florida, California, and New Mexico were taken to a separate laboratory, where no avian work was being conducted. Using all new stock solutions, DNA was purified and amplified. PCR reactions were conducted under UV light as an additional precaution against contamination. All unique sequences were deposited in Genbank under the following accession numbers:

nkit 423326, 423334, 424445, 424887, 423676, 424455, 423688, 423690, 424905, 424907, 423692.

RESULTS

Cytochrome b Sequences. A single 297 bp fragment of the cytochrome b gene was consistently amplified for Burrowing, Elf, Barred, and Eastern Screech Owls, all of which were sequenced. Using the same primers, fragments of similar size have been amplified for other bird species (Kocher et al. 1989, Edwards and Wilson 1990, Birt-Friesen et al. 1992). Compared to sequences deposited in the Genbank, owl sequences were most similar to other avian cytochrome b sequences. The nucleotide content of the cytochrome b sequences were consistent with other published avian cytochrome b sequences showing a lower guanine (G) content and above average cytocine (C) content (Table 1). Also in agreement with other avian cytochrome b sequences, a third codon deficiency of G and thymine (T) was observed (Table 2).

Maximum parsimony analysis of the cytochrome b data was conducted with PAUP (version 3.1.1; Swofford and Begle 1993) using the heuristic search algorithm (Elf, Barred, and Eastern Screech Owls were designated as outgroups). Unweighted maximum parsimony analysis separated Burrowing Owls from North and South America, and bootstrap analysis (500 replications) provided strong support for this separation with a value of 100%.

Cytochrome B Intraspecific Sequence Divergence. Within the 297 bp segment of the cytochrome b region, 15 positions were variable among all samples (Appendix). With one exception, variable positions were transitions. There were 11 substitutions in third codon positions between North and South American Burrowing Owls. There was one substitution in the first position of a codon between North American Burrowing Owls (*A. c. hypugaea* and *A. c. floridana*) and *A. c. cunicularia* from Argentina, and two substitutions were in the first position of a codon between North American Burrowing Owls and *A. c. nanodes* and *A. c. punensis*, which resulted in one amino acid change (Appendix). The western (*A. c. hypugaea*) and Florida (*A. c. floridana*) Burrowing Owls each differed from the Peru (*A. c. nanodes*) and Ecuador (*A. c*

Table 2. Percent nucleotide distribution at first, second, and third codon positions of 297 bp cytochrome b fragment for Burrowing, Elf, Barred, and Eastern Screech Owls.

	FIRST				SECOND				THIRD			
	A	G	C	T	A	G	C	T	A	G	C	T
Athene cunicularia	23	26	24	27	16	20	27	34	26	7	59	7
Micrathene whitneyi	26	24	26	25	20	19	25	37	38	3	48	10
Strix varia	24	25	24	26	24	18	28	36	28	7	55	9
Otus asio	23	26	28	23	21	19	24	36	28	7	53	9

Table 3. Pairwise distances (based on cytochrome b data) among taxa. Above the diagonal are absolute distances and below the diagonal are total number of observed differences. Total number of observed differences equals number of transitions plus transversions; number of transversions are in parentheses.

TAXA	1	2	3	4	5	6	7	8
1. *A. c. hypugaea*	—	0.007	0.040	0.044	0.044	0138	0.185	0.178
2. *A. c. floridana*	2 (0)	—	0.040	0.044	0.044	0.138	0.178	0.178
3. *A. c. cunicularia*	12 (0)	12 (0)	—	0.010	0.010	0.135	0.168	0.168
4. *A. c. nanodes*	13 (1)	13 (1)	3 (0)	—	0.000	0.135	0.168	0.168
5. *A. c. punensis*	13 (1)	13 (1)	3 (0)	0 (0)	—	0.135	0.168	0.168
6. *Micrathene whitneyi*	41 (19)	41 (19)	40 (19)	40 (19)	40 (19)	—	0.135	0.152
7. *Otus asio*	55 (22)	55 (22)	50 (23)	50 (23)	50 (23)	40 (16)	—	0.135
8. *Strix varia*	53 (19)	53 (19)	50 (16)	50 (16)	51 (16)	45 (19)	40 (18)	—

punensis) forms by 12 transitions and one transversion (percent divergence: $P = 4.4$) and the Argentinean form (*A. c. cunicularia*) by 12 transitions ($P = 4.0$). The western and Florida Burrowing Owls differed by two transitions (percent nucleotide divergence: $P = 0.7$). The Argentinean Burrowing Owls (*A. c. cunicularia*) differed from Burrowing Owls of coastal Ecuador (*A. c. punensis*) and Peru (*A. c. nanodes*) by three transitions ($P = 1.0$), and no differences were observed between *A. c. nanodes* and *A. c. punensis* (Table 3).

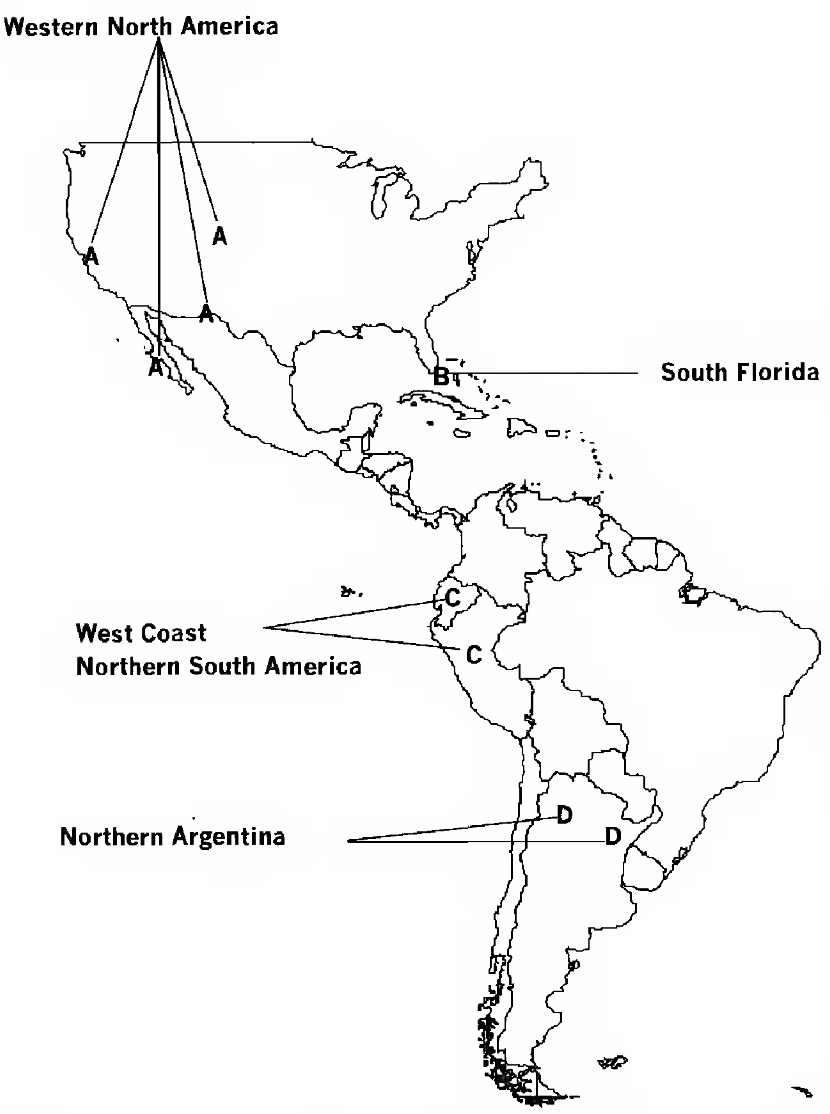

Figure 1. Geographic localities of the distinct mtDNA genotypes: A = *Athene cunicularia hypugaea,* B = *A. c. floridana,* C = *A. c. nanodes* and *A. c. punensis,* D = *A. c. cunicularia.*

Rates of Evolution. Wood and Krajewski (1996) estimated the rate of evolution of cytochrome b sequences for cranes (*Sarus* spp.) to be 1.7% per 1 million yr, lending support to the molecular clock calibration of 2% sequence divergence per million yr by Brown et al. (1982). Applying this conventional mammalian mtDNA molecular clock calibration of 2% sequence divergence per million yr to the cytochrome b sequence data, we estimate that the North and South American forms of the Burrowing Owl diverged ca. 2 million yr ago. Of the three South American subspecies examined, *A c. cunicularia* diverged from *A. c. punensis* and *A. c nanodes* ca. 500 000 yr ago, and coastal populations representing *A. c. nanodes* and *A. c. punensis* of Peru and Ecuador showed no evidence of divergence. The two North American subspecies (*A. c. hypugaea* and *A. c. floridana*) diverged more recently, ca. 350 000 yr ago (Fig. 1). This molecular clock has been widely applied to various taxa; however, given uncertainties about mtDNA clocks in birds and other taxa (Rising and Avise 1993), this estimate should be cautiously interpreted. Rates of evolution were not determined among owl species using cytochrome b data due to the saturation of nucleotide substitutions.

DISCUSSION

Cytochrome b Sequences. The cytochrome b sequences obtained for Burrowing Owls and other owl species were in agreement with other published avian cytochrome b sequences (Kocher et al.

1989, Birt-Friesen et al. 1992, Wood and Krajewski 1996). Like other avian cytochrome b sequences, all four owl species exhibited a deficiency of guanine. When nucleotide distribution was examined in relation to codon position, the four owl sequences exhibited a pattern similar to other avian taxa, exhibiting a deficiency for both guanine and thymine at third codon positions. The guanine deficiency also has been reported in rodents and fish (Kocher et al. 1989). A deficiency in both guanine and thymine at the third codon position has only been reported for avian species (Kocher et al. 1989, Quinn and Wilson 1993).

The level of variability detected within and between Burrowing Owl populations from North and South America, using cytochrome b, is higher than, but consistent with, the level of cytochrome b variability detected in other avian studies that make intraspecific comparisons (Edwards and Wilson 1990, Wenink et al. 1993). The agreement in observed nucleotide composition with other avian species, and the similarity in levels of observed variability within other avian species suggests that the cytochrome b sequence data for the four owl species is authentic mitochondrial cytochrome b sequence. In addition, the amino acid translations for the nucleotides did not reveal any stop codons interrupting translation that would indicate a nonfunctional copy.

Distribution and Divergence of Cytochrome b Sequences. Cytochrome b sequence results revealed a clear split between Burrowing Owls from North and South America (4.0–4.4% divergence). The sequence data contained numerous diagnostic sites for North and South American Burrowing Owls. The depth of this split is consistent with species-level distinction that has been described in other studies using this molecular marker (Edwards and Wilson 1990, Birt-Friesen et al. 1992, Wood and Krajewski 1996) and studies using restriction endonucleases on mtDNA (Kessler and Avise 1984, Mack et al. 1986, Shields and Wilson 1987). Within-genus sequence divergence among *Sarus* cranes (Wood and Kajewski 1996) is similar to divergence values between North and South American populations of Burrowing Owls. Several studies examining sibling taxa (Kessler and Avise 1984, Shields and Wilson 1987, Avise and Zink 1988) report lower values for genetic distances than observed between North and South American forms of the Burrowing Owl. The one notable exception is the study on Australian Babblers (*Pomatostomus temporalis* Edwards and Wilson 1990), which reports large within-subspecies values for genetic distance using cytochrome b. They report a mean of 1.4% and 1.3% within northern and southern groups of *P. temporalis*, respectively, and a mean of 3.2% between the northern and southern forms. They comment that this degree of divergence is large for subspecific status and suggest further investigation into the specific status of the bird. The even greater mtDNA distances between the North and South American forms of the Burrowing Owl reported here suggest that the species status of these owls should also be reevaluated. The distances observed between *A. c. hypugaea* and *A. c. floridana* for North America and between *A. c. cunicularia* and *A. c. nanodes/punensis* for South America are consistent with subspecies-level distinctions that have been observed in other studies.

Although a strong split between Burrowing Owls from North and South America was detected, we cannot geographically define exactly where the split occurs because of our limited sampling. It most likely occurs in Central America or extreme northern South America (i.e., Colombia). A more intensive sampling effort between the areas in question would determine whether or not this break is between two distinct clades.

Biogeographic Patterns. The divergence of North and South American forms of the Burrowing Owl ca. 2 million yr ago coincides with the presence of the isthmian land bridge, which arose at that time, providing a dispersal corridor between continents. The mingling of the North and South American faunas is postulated to have spanned a 2 million yr period between the last million years of the Pliocene and the first million years of the Pleistocene (from 3 until 1 million yr ago). Webb (1978) estimated that a large portion (2/3 for mammals) of the faunal exchange involved savanna-adapted organisms. The presence of the Burrowing Owl ancestor in the North American fossil record dating back to the Pliocene, and South American fossil records of the Burrowing Owl from the Pleistocene, may indicate that these birds evolved in North America and subsequently dispersed to the South American continent; however, the sparse fossil record may be misleading. The climatic fluctuations in South America associated with glacial and interglacial periods resulted in isolated patches of suitable habitat that ranged from small to large expanses of grasslands and savanna-type habitats. The disjunct distribution of suitable habitat throughout South America helps explain the diversity among Burrowing Owl populations on that continent (11 recognized subspecies). The genetic divergence observed between cytochrome b sequences of Burrowing Owls from North and South America is large and warrants further investigation regarding full species status. Verification of the observed cytochrome b sequence divergence with nuclear markers, morphology and/or other ecological indicators, such as vocalizations or behavior, is needed.

ACKNOWLEDGMENTS

We would like to acknowledge several individuals and institutions whose support made this project possible. Tissue samples from museum collections were provided by David Agro at the Philadelphia Academy of Natural Sciences, Donna Dittman at Louisiana State Museum, Scott Edwards at the Burke Museum, and Brian Schmidt at the Smithsonian Museum of Natural History. Susie Durnham at the Univ. Nevada-Reno and the North Carolina Zoo provided purified genomic DNA of Elf Owls. Brian Mealy collected and sent blood samples from Florida. Marian Langan, Stefan Penas, and Julia Smith provided field assistance. Penny Delevoras, Lynne Trulio, Kent Livsey, Sergeant Chris Shadduck, Greg Green, Bruce Besken, Pete McDonald, Eugene Botelho, and the staff of the Umadilla National Wildlife Refuge provided assistance with field logistics and locating Burrowing Owls outside of Nebraska. Financial support was provided by grants from the Center for Biotechnology at the Univ. Nebraska, the Frank M. Chapman Fund at the Museum of Natural History in New York, and a Stephen Tully Memorial Grant from the Raptor Research Foundation. We would like to thank B.J. Adams, B. Johnson, N. Korfanta, and K.P. Pruess for reviewing this manuscript. This is New Mexico Agricultural Experiment Station publication No. NM-014724-01-00, supported by state funds and the U.S. Hatch Act.

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Appendix. Nucleotide and inferred amino acid sequences of 297 bp fragment of the cytochrome b gene for Burrowing Owl subspecies and the Elf, Eastern Screech, and Barred Owls. Sequence orientation is from 5′ to 3′ on the light strand. Dots indicate identity with *A. c. hypugaea* sequences, and dashes indicate gaps in sequences. Sites in bold are amino acid replacements within Burrowing Owls, and sites in italics indicate amino acid replacements among owl species.

A. c. hypugaea[a]	C	TTC	GGA	TCC	CTG	CTA	GGC	ATC	TGC	TTG	ACA	ACT	CAG	ATC	ATT
A. c. hypugaea[b]	.	...	...	...	...	...	...	...	...	...	...	...	...	...	...
A. c. hypugaea[c]	.	...	...	...	...	...	...	...	...	...	...	...	...	...	...
A. c. floridana[d]	.	...	...	...	...	...	...	...	...	...	...	..C	...	...	...
A. c. cunicularia[e]	.	...	...	...	..A	...	...	...	...	...	...	..C	...	...	...
A. c. cunicularia[f]	.	...	...	...	..A	...	...	...	...	...	...	..C	...	...	...
A. c. nanodes[g]	.	...	...	...	..A	...	...	...	...	...	...	..C	...	...	...
A. c. punensis[h]	.	...	...	...	..A	...	...	...	...	...	...	..C	...	...	...
Micrathene whitneyi	.	...	...	..T	..A	..T	...	...	...	C.A	.T.	..C	..A	...	..C
Otus asio	.	...	..G	...	...	..T	..A	..T	...	C.A	.T.	G.C	..A	...	..C
Strix varia	.	...	..G	...	..A	T..	..A	...	..T	C.A	G..	..C	..A	...	..C
		phe	gly	ser	leu	leu	gly	ile	cys	leu	*thr*	*thr*	gln	ile	ile
A. c. hypugaea	ACT	GGC	CTC	TTA	CTA	GCC	ACC	CAC	TAC	ACA	GCC	GAC	TCC	TCC	
A. c. hypugaea	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
A. c. hypugaea	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
A. c. floridana	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
A. c. cunicularia	...	...	...	C..	...	...	...	...	...	...	...	...	...	...	
A. c. cunicularia	...	...	...	C..	...	...	...	...	...	...	...	...	...	...	
A. c. nanodes	...	...	...	C..	...	...	...	...	...	...	...	...	...	...	
A. c. punensis	...	...	...	C..	...	...	...	...	...	...	...	...	...	...	
Micrathene whitneyi	...	...	...	C..	...	...	..A	..T	...	...	A.T	...	..A	A..	
Otus asio	..A	...	...	C..	..C	...	..A	...	..T	...	...	...	..A	A..	
Strix varia	...	...	...	C.C	..T	..A	G..	...	..T	...	...	...	..A	G..	
	thr	gly	leu	leu	leu	ala	*thr*	his	tyr	thr	*ala*	asp	ser	*ser*	
A. c. hypugaea	CTG	GCC	TTC	ACA	GCT	GTC	TCA	CAC	ACA	TGC	CGA	GAC	GTC	CAA	
A. c. hypugaea	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
A. c. hypugaea	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
A. c. floridana	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
A. c. cunicularia	..A	...	...	...	..C	...	...	...	...	...	...	...	...	...	
A. c. cunicularia	..A	...	...	...	..C	...	...	...	...	...	...	...	...	...	
A. c. nanodes	..A	...	...	...	...	...	...	...	...	...	...	A..	...	...	
A. c. punensis	..A	...	...	...	...	...	...	...	...	...	...	A..	...	...	
Micrathene whitneyi	..A	...	..T	...	T.A	..A	..C	..T	...	...	...	...	...	...	
Otus asio	..A	..A	...	...	T.C	..A	...	...	..C	...	...	..T	..G	...	
Strix varia	..A	...	...	G..	..C	..A	..C	...	..C	...	...	A..	A..	...	
	leu	ala	phe	*thr*	*ala*	val	ser	his	thr	cys	arg	***asp***	*val*	gln	
A. c. hypugaea	TAC	GGC	TGA	CTC	ATC	CGC	AAC	CTC	CAT	GCA	AAC	GGG	GCA	TCC	
A. c. hypugaea	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
A. c. hypugaea	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
A. c. floridana	..T	...	...	...	...	...	...	...	...	...	...	...	...	...	
A. c. cunicularia	...	...	...	...	...	...	...	...	..C	...	...	..A	...	...	
A. c. cunicularia	...	...	...	...	...	...	...	...	..C	...	...	..A	...	...	
A. c. nanodes	...	...	...	...	...	...	...	...	..C	...	...	..A	...	...	
A. c. punensis	...	...	...	...	...	...	...	...	..C	...	...	..A	...	...	
Micrathene whitneyi	...	..A	...	..A	...	...	...	...	...	...	..T	..A	..C	..A	
Otus asio	..T	...	...	..A	C.A	...	...	...	..C	..G	..T	..A	..C	..A	
Strix varia	...	...	...	...	..A	...	...	...	..C	...	...	...	..C	..A	
	tyr	gly	trp	leu	*ile*	arg	asn	leu	his	ala	asn	gly	ala	ser	

Appendix. Continued.

A. c. hypugaea	ATA	TTC	TTT	ATC	TGC	ATC	TAC	CTC	CAC	ATC	GGA	CGA	GGC	CTA
A. c. hypugaea	...	...	...	...	...	...	...	...	...	...	...	...	...	...
A. c. hypugaea	...	...	...	...	...	...	...	...	...	...	...	...	...	...
A. c. floridana	...	...	...	...	...	...	...	...	...	...	...	...	...	...
A. c. cunicularia	..G	...	..C	...	...	...	...	...	...	..T	...	..G	...	T..
A. c. cunicularia	..G	...	..C	...	...	...	...	...	...	..T	...	..G	...	T..
A. c. nanodes	..G	...	..C	...	...	...	...	...	...	..T	...	..G	...	T..
A. c. punensis	..G	...	..C	...	...	...	...	...	...	..T	...	..G	...	T..
Micrathene whitneyi	..C	...	...	...	...	...	...	..A	...	...	...	...	...	A..
Otus asio	..T	...	..C	...	...	...	...	..A	...	...	...	..G	...	...
Strix varia	C.C	...	..C	...	...	...	...	..G	...	...	...	...	...	...
	ile	phe	phe	ile	cys	ile	tyr	leu	his	ile	gly	arg	gly	*leu*
A. c. hypugaea	TAC	TAC	GGC	TCA	TAC	CTC	TAC	AAA	GAA	ACC	TGA	AAC	ACA	GGT
A. c. hypugaea	...	...	...	...	...	...	...	...	...	...	...	...	...	...
A. c. hypugaea	...	...	...	...	...	...	...	...	...	...	...	...	...	...
A. c. floridana	...	...	...	...	...	...	...	...	...	...	...	...	...	...
A. c. cunicularia	...	...	...	...	...	...	...	...	...	...	...	...	...	...
A. c. cunicularia	...	...	...	...	...	...	...	...	...	...	...	...	...	...
A. c. nanodes	...	...	...	...	...	...	...	...	...	...	...	...	...	...
A. c. punensis	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Micrathene whitneyi	...	...	...	..T	...	...	...	...	...	...	...	...	...	..A
Otus asio	...	...	...	..C	...	..A	...	...	...	...	...	...	...	...
Strix varia	...	...	...	..C	..T	..G	...	...	..G	...	...	..T	...	...
	tyr	tyr	gly	ser	tyr	leu	tyr	lys	glu	thr	trp	asn	thr	gly
A. c. hypugaea	GTC	CTA	CTT	CTC	TTG	ACC	CTA	ATA	GCC	ACC	GCC	TTC	GTG	GGC
A. c. hypugaea	...	...	...	...	...	...	...	...	...	...	...	...	...	...
A. c. hypugaea	...	...	...	...	...	...	...	...	...	...	...	...	...	...
A. c. floridana	...	...	...	...	...	...	...	...	...	...	...	...	...	...
A. c. cunicularia	...	...	...	...	...	...	...	...	...	...	...	...	...	...
A. c. cunicularia	...	...	...	...	...	...	...	...	...	...	...	...	...	...
A. c. punensis	...	...	...	...	...	...	..G	...	...	...	...	...	...	...
A. c. nanodes	...	...	...	...	...	...	..G	...	...	...	...	...	...	...
Micrathene whitneyi	...	N..	..C	...	C..	...	...	...	..A	..A	..N	...	...	...
Otus asio	...	...	..C	..A	C..	...	..T	...	..A	..T	..T	...	...	...
Strix varia	A.T	...	T.A	...	...	...	...	...	..T	...	...	..A	...	...
	val	leu	leu	leu	leu	thr	leu	ile	ala	thr	ala	*phe*	val	gly
A. c. hypugaea	TA													
A. c. hypugaea	..													
A. c. hypugaea	..													
A. c. floridana	..													
A. c. cunicularia	..													
A. c. cunicularia	..													
A. c. nanodes	..													
A. c. punensis	..													
Micrathene whitneyi	..													
Otus asio	..													
Strix varia	..													

[a] Collected in Baja California, Mexico.
[b] Collected in western Nebraska, U.S.A.
[c] Collected in central California, U.S.A.
[d] Collected in southern Florida, U.S.A.
[e] Collected in Providence Corrientes, Argentina.
[f] Collected in Providence Tucuman, Argentina.
[g] Collected in Providence Trujulio, Peru.
[h] Collected in Providence Loja, Ecuador.

J Raptor Res. 35(4):282–287

DISPERSAL PATTERNS AND POST-FLEDGING MORTALITY OF JUVENILE BURROWING OWLS IN SASKATCHEWAN

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ABSTRACT.—The dramatic decline of Burrowing Owls (*Athene cunicularia*) in Saskatchewan, Canada, during the 1980s and 1990s coincided with low return rates of 1-yr-old birds, suggesting factors affecting the survival of post-fledging juveniles may be crucial to maintaining population sizes. In 1997 and 1998, I used radiotelemetry to study survival and dispersal of juvenile Burrowing Owls between fledging and migration on the Regina Plain in southern Saskatchewan. The mortality rate of radio-tagged juveniles was significantly lower in 1997 (0%, N = 12 owls) than in 1998 (45.4%, N = 33 owls). Compared to the lack of predation on radio-tagged owls in 1997, avian predators were a major cause of mortality in 1998, accounting for 47% of the 15 deaths. Other sources of mortality included mammalian predation, collisions with vehicles, starvation, collision with barbed-wire fences, and siblicide. Juvenile owls dispersed significantly farther from their natal burrows before migration in 1997 (1297 ± 526 m, N = 10) than in 1998 (449 ± 98 m, N = 18). These differences in dispersal and mortality between years may have been related to the high abundance of voles (*Microtus* spp.) on the Canadian plains in 1997. Three general patterns of post-fledging dispersal were exhibited by radio-tagged juveniles in both years of the study. Dispersal patterns were affected by habitat continuity, with a trend toward "multiple-roost" dispersal in the most continuous habitat.

KEY WORDS: *Burrowing Owl;* Athene cunicularia; *post-fledging; mortality; dispersal; predation; habitat fragmentation; Saskatchewan.*

Patrones de dispersion y mortalidad post-emplumamiento de Búhos Cavadores juveniles en Saskatchewan

RESUMEN.—El dramático decline de los Búhos Cavadores (*Athene cunicularia*) en Saskatchewan, Canadá, durante los '80s y '90s coincidió con las bajas tasas de retorno de aves de 1 año de edad, esto sugiere que los factores que afectan la supervivencia de los juveniles post-emplumamiento puede ser crucial para mantener el tamaño de la población. En 1997 y 1998, use radio-telemetría para estudiar la supervivencia y dispersión de Búhos Cavadores juveniles entre el emplumamiento y la migración en la Llanura de Regina en el sur de Saskatchewan. La tasa de mortalidad de juveniles provistos con radios fue significativamente mas baja en 1997 (0%, N = 12 búhos) que en 1998 (45.4%, N = 33 búhos). Esta diferencia en la mortalidad entre años puede haber estado relacionada con la alta abundancia de ratones *Microtus* en la Llanuras Canadienses en 1997. En comparación a la completa ausencia de depredación de búhos marcados con radios en 1997, los depredadores aéreos fueron la mayor causa de mortalidad en 1998, dando cuenta del 47% de las 15 muertes. Otras causas de mortalidad incluyen la colisión con vehículos, inanición, colisión con cercas de alambre de púas, conflicto cain–abel/canibalismo, y causa desconocidas. La mortalidad en 1998 fue mas alta en parches aislados de pastos (<1600 m^2) que en parches continuos (>1600 m^2). Tres patrones generales de dispersión pos-emplumamiento fueron exhibidas por juveniles marcados con radios en los dos años del estudio. Los patrones de dispersión fueron afectados por la continuidad del hábitat, con una fuerte tendencia hacia la dispersión del tipo "múltiples-perchas" en los hábitats mas continuos.

[Traducción de Victor Vanegas y César Márquez]

Burrowing Owl (*Athene cunicularia*) populations across the Canadian prairies have undergone severe declines in the 1980s and 1990s (Wellicome and Haug 1995, James et al. 1997). Extensive research has been conducted on the ecology of Burrowing Owls on the Canadian breeding grounds (Haug 1985, Warnock 1996, Schmutz 1997, Wellicome et al. 1997, Wellicome 2000). However, the causes of the decline have yet to be determined. Most of this research was concluded by the time

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the juveniles fledge (but see King 1996 and Clayton 1997). Identifying factors that affect survival during the post-fledging, premigratory life-history stage is an important part of understanding population dynamics of the Burrowing Owl, and may provide vital information regarding the decline.

This paper describes results of a project recording dispersal patterns and mortality rates of juvenile Burrowing Owls in a highly-fragmented landscape. The study took place during the summers of 1997–98, and concentrated on the post-fledging/premigratory life stage. A fortuitous outbreak of voles (*Microtus* spp.) across the Canadian prairies in the spring of 1997 caused *Microtus* populations to reach levels not attained in the area since 1969 (Poulin et al. 2001). In 1998, vole populations returned to normal levels. The difference in prey abundance between the two years of this study allowed the comparison of juvenile survival and dispersal between a year of high and a year of normal prey abundance.

Study Area and Methods

This project was conducted in southern Saskatchewan, on the Regina Plain, during 1997 and 1998. The study area encompassed approximately 12 200 km^2 in the grassland ecoregion (Harris et al. 1983), south of the cities of Moose Jaw (50°34′N, 105°17′W) and Regina (50°25′N, 104°39′W). More than 90% of the land on the Regina Plain is cultivated for production of cereal crops. The remnant grassland is highly fragmented and confined to small sections of pasture, isolated from other grassland patches by several kilometers. Because of a lack of burrows, the cropland matrix separating grassland patches is largely unavailable to Burrowing Owls for nesting, so the owls nest almost exclusively in pastures. The nesting density of Burrowing Owls in the study area is low, usually with only one or two owl pairs in each occupied pasture.

The length of the post-fledging period in raptor species ranges from a few weeks to several months (Newton 1979), but the exact timing is often difficult to determine. Therefore, in migratory species, the initiation of migration is often used to mark the end of the post-fledging period (Beske 1982, Sherrod 1983). Because Burrowing Owls nest underground and owlets can easily walk away from the nests, it is difficult to ascertain exact fledging dates. In addition, most juveniles in this study area remain on their natal territories until they migrate, making it difficult to determine the date of independence (i.e., when the post-fledging period ends). I therefore defined the post-fledging period for each juvenile owl as beginning when it made its first movement to a burrow other than its natal burrow (initiation of dispersal), and ending when it migrated from the breeding grounds.

Necklace-style radio-transmitters (Holohil Systems Ltd., Ontario, Canada), weighing 6 g (ca. 4% of adult body mass), were fitted onto one juvenile owl per nest at 45 nests (12 in 1997 and 33 in 1998). Nests included in the study were chosen randomly from available nests. Each transmitter was attached when the owlet was between 30–35 d post-hatch, immediately prior to initial dispersal. Owls were assigned ages based on the hatching day of the first hatchling in each nest. Owls were captured either inside artificial nest boxes (Wellicome et al. 1997) or using noose carpets baited with dead laboratory mice. Transmitter signals were detected using a portable receiver (Lotek SRX 400) and either a 2- or 3-element Yagi antenna, or an omni-directional, vehicle roof-mounted antenna. The location of each radio-tagged owl was determined every 2–3 d from the date its transmitter was attached until the owl died or left the study area. When signals could not be detected from the ground, aerial searches were conducted with a single-engine Cessna 172 equipped with radio-tracking gear.

At each diurnal roost (hereafter, satellite burrow) used by juvenile owls during the post-fledging period, I measured the distance and direction from the natal burrow. Distances <500 m were determined by pacing or using a 50-m measuring tape. Aerial photographs, aided by Global Positioning System (GPS) readings, were used to determine distances >500 m. To avoid influencing dispersal behavior, I tried to minimize disturbance to the owls while tracking. Therefore, whenever possible, the position of radio-tagged owls was determined using binoculars or a spotting scope, and measurements of dispersal distances were taken after the juvenile owl had moved to a different satellite burrow.

To categorize dispersal patterns, I constructed graphs for each radio-tagged juvenile, comparing distance from nest with age of the juvenile owl. Individuals were then grouped according to their dispersal profiles. The first movement made by a radio-tagged owl to a burrow other than the natal one was classified as initiation of dispersal. King (1996) and Clayton (1997) defined commencement of juvenile dispersal as a permanent movement away from the natal burrow of 300 m and 500 m, respectively. I chose to treat each movement as a dispersal event, regardless of the distance traveled, because the small patch size and lack of habitat continuity in some nesting areas may have severely limited the possibility of larger movements.

I classified nest sites as occurring in either "continuous" or "isolated" habitat, depending on the size and position of the site relative to other patches of grassland. In general, pastures ≤64 ha (one quarter-section), surrounded on all sides by cultivated fields (i.e., requiring the owl to fly over cropland to get to the next pasture) were classified as isolated. Pastures >64 ha were classified as continuous habitat.

Carcasses of dead Burrowing Owls were examined to determine cause of death. Mortality events were classified as: 1) avian predation (plucked feathers, usually in the same location as the transmitter); 2) mammalian predation (carcass, feathers, and/or transmitter chewed, with whole wings or legs bitten off and left at the site); 3) starvation (intact, emaciated carcass); 4) road kill (found dead on or near the road with evidence of a vehicle collision); 5) siblicide/cannibalism (remains of juvenile found inside nest box, usually with head partially eaten or missing; Wellicome 2000); or 6) unknown causes.

Differences in dispersal activities between years were

Table 1. Dispersal activities (mean ± SE) of radio-tagged juvenile Burrowing Owls in Saskatchewan. *P*-values are from two-tailed Student's *t*-tests. Sample sizes are shown in square brackets.

VARIABLE	1997	1998	COMBINED YEARS	P
Age at first dispersal[a] (d)	45.8 ± 4.7 [5]	46.2 ± 1.4 [26]	46.1 ± 1.3 [31]	0.92
Closest occupied satellite burrow (m)	38.4 ± 10.1 [11]	45.6 ± 9.4 [27]	43.5 ± 7.2 [38]	0.66
Age at final sighting (d)	102.3 ± 4.6 [10]	107.8 ± 2.0 [18]	105.9 ± 2.1 [28]	0.21
Date of final sighting[b] (d)	23 Sept ± 2.6 [10]	24 Sept ± 1.8 [18]	24 Sept ± 1.5 [28]	0.84
Farthest distance from nest before migration[c] (m)	1297.8 ± 526 [10]	448.9 ± 97.9 [18]	752.1 ± 207.3 [28]	0.05

[a] Age that individual was first observed at a burrow other than its nest.
[b] An estimate of the onset of fall migration.
[c] Distances were included for all three dispersal patterns (see text).

assessed using two-tailed Student's *t*-tests. Following the Bonferroni procedure for multiple comparisons, the alpha level for each *t*-test was set at 0.01 to assure an overall significance level of 0.05 (Zar 1996). Differences in the occurrence of dispersal patterns between the two habitat types were tested using a 2 × 3 contingency table.

RESULTS

Post-fledging Activities. There were no significant differences between years in any dispersal activities, with the exception of the farthest distance traveled by a juvenile owl before migration (Table 1). Radio-tagged juveniles were found significantly farther from their natal burrows before migration in 1997 than in 1998. In both years, radio-tagged juveniles began first movements away from natal burrows at 28–57 d post-hatch, and began migration at 89–124 d. The median ages of first dispersal and final sighting were 47.0 and 109.5 d post-hatch, respectively. The median date of final sighting, an estimate of the onset of fall migration, was 26 September (mean ± SE = 24 September ± 1.5 d). Before migration, each juvenile owl used a mean of 5.7 ± 0.5 satellite burrows.

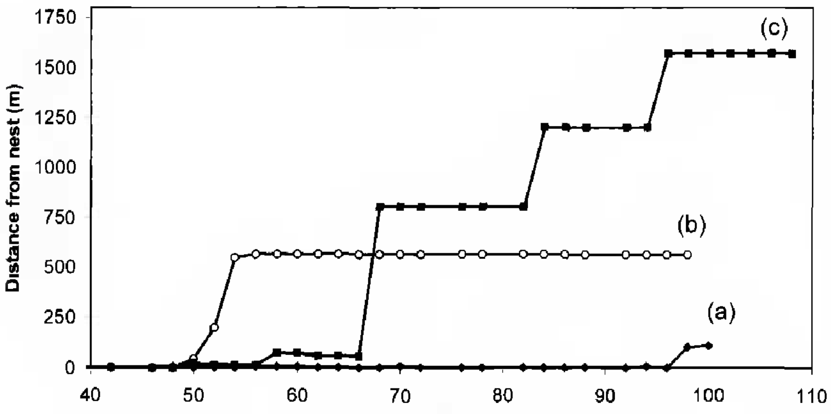

Figure 1. Illustrations of the three patterns of juvenile dispersal exhibited by radio-tagged Burrowing Owls in Saskatchewan in 1997 and 1998: (a) nest-centered dispersal, (b) single-roost dispersal, (c) multiple-roost dispersal.

Dispersal Patterns. In each of the two years, owls exhibited three patterns of post-fledging dispersal: 1) nest-centered, 2) single-roost, and 3) multiple-roost dispersal. In nest-centered dispersal (Fig. 1a), juveniles remained close to their natal burrow for the majority of the post-fledging period (i.e., >50 d), dispersing only to satellite burrows in the immediate vicinity of their nest. These juveniles remained within a mean (±SE) of 139.4 ± 55.2 m (N = 9 owls) of their nest until abruptly leaving the area for migration. In single-roost dispersal (Fig. 1b), juveniles dispersed to a burrow, or cluster of burrows, apart from their nest and remained in that area until migration, without returning to their natal burrow. The satellite burrows for this type of dispersal averaged 859.2 ± 378.8 m (N = 10 owls) from the nest. In multiple-roost dispersal (Fig. 1c), juveniles moved farther and farther away from their nest burrow, choosing a new burrow or cluster of burrows on each step and remaining there for a few days before moving again. Owls exhibiting this latter type of dispersal behavior were farthest from their nests by the end of the post-fledging period, dispersing an average (±SE) of 1534.1 ± 545.2 m (N = 9 owls) from their nests before migrating.

The three types of dispersal occurred in approximately equal proportions (χ^2 = 0.071, df = 2, P > 0.05, N = 28 owls), with slightly fewer juveniles exhibiting multiple-roost (32%, N = 9) or nest-centered (32%, N = 9) than single roost (36%, N = 10) dispersal. There was a significant difference (χ^2 = 6.720, df = 2, P < 0.05) between the dispersal

Table 2. Distribution of dispersal patterns exhibited by radio-tagged Burrowing Owls in continuous and isolated habitat patches.

		Habitat Type	
Dispersal Pattern	Percent Occurrence	Contin-uous	Isolated
Nest-centered	32	5	4
Single-roost	36	3	7
Multiple-roost	32	8	1

patterns exhibited in isolated and continuous habitats. Multiple roost dispersal occurred eight times more often in continuous than in isolated habitat patches (Table 2).

Mortality. Post-fledging mortality of juvenile owls was substantially lower in 1997 than in 1998. None of the 12 radio-tagged juveniles were known to have died in 1997, whereas 45.4% of the 33 radio-tagged owls died before migration in 1998 (Table 3). Most mortality occurred shortly after juveniles left the nest (mean ± SE = 11.7 ± 5.5 d, median = 4.9 d after initial dispersal), with the exception of one juvenile that failed to migrate and was found dead of unknown causes in its nest burrow early in October. Most mortality (67%, N = 15 deaths) occurred in isolated habitat patches, and half of these deaths were due to avian predators.

Avian predation accounted for 47% (N = 15 deaths) of the overall mortality in 1998. This mortality rate may be biased because, of the seven deaths caused by avian predators, three occurred at nests within a single pasture. However, even when multiple nests within a pasture are excluded from the analysis (resulting in 10 deaths, rather than 15), and only one randomly chosen nest per field is included, the trend remains the same, with most mortality (60%, N = 10) occurring in isolated habitat patches with avian predators as the predominant factor (40%, N = 10). Other sources of mortality included road kill (7%), starvation (13%), collision with barbed-wire fences (7%), siblicide/cannibalism (7%), and unknown causes (13%).

Table 3. Cause-specific mortality for juvenile Burrowing Owls in Saskatchewan. 'Percent Dead' = 'No. of Dead'/ total No. of radio-tagged juveniles. The overall mortality rate in 1997 was 0% (N = 12), and 45.4% (N = 33) in 1998.

Year	Cause of Death	No. Dead	Percent Dead
1997	(Not applicable)	0	0
1998	Predation	8	24.2
	(Avian)	(7)	(21.2)
	(Mammalian)	(1)	(3.0)
	Road kill	1	3.0
	Starvation	2	6.1
	Barbed wire	1	3.0
	Siblicide/cannibalism	1	3.0
	Unknown	2	6.1
	Total	15	45.4

Discussion

Prior to the conversion of native prairie to cropland, Burrowing Owls in Canada presumably had access to large expanses of continuous grassland. Beyond the direct negative impacts associated with extensive habitat loss, habitat fragmentation can affect such things as the dispersal ability of Burrowing Owls. Results from this study suggest that Burrowing Owls exhibit multiple-roost dispersal behavior more often in continuous grassland than in isolated habitat patches. This pattern of dispersal may have been the most common pattern of dispersal in pre-European settlement days. Most radio-tagged juvenile owls (10 of 13) in a less-fragmented, shrub-steppe habitat in Idaho (King 1996) dispersed in a manner comparable to the multiple-roost pattern described in this study. The highly-fragmented landscape in the Regina Plain may necessitate other behaviors, such as foregoing large dispersal movements and remaining close to their natal burrow until migration. It is not clear, however, which dispersal pattern may maximize Burrowing Owl fitness.

The disparity in mortality rates between isolated and continuous habitat patches suggests that lack of habitat continuity may be associated with risk of predation. Elevated predation rates in relation to habitat fragmentation have been reported for other avian species (Whitcomb et al. 1980, Ambuel and Temple 1983, Andrén et al. 1985). Because predation events can often result from an incidental encounter between predator and prey (Angelstam 1986, Vickery et al. 1992), the probability of a predation event may be higher in smaller habitat patches (Burger et al. 1994). On the prairies, the increase in the number and density of trees that accompany farms and cities has likely compounded the habitat loss associated with the conversion of grasslands to crops, allowing some avian predator populations to increase (Schmutz et al. 1980). Trees provide potential nesting sites for Great Horned Owls (*Bubo virginianus*), Swainson's Hawks (*Buteo swainsoni*), and Red-tailed Hawks (*B. jamaicensis*), which were not as abundant on the previously treeless prairies (Wellicome 1997). Habitat fragmentation and an elevated density of avian predators likely results in the concentration of Burrowing Owls and their predators in small patches of prairie, and probably increases predation risk to Burrowing Owls nesting in such areas.

The annual difference in juvenile mortality may have resulted directly or indirectly from the abundance of voles (*Microtus* spp.) in 1997 (Poulin et al. 2001). The high abundance of voles provided ample food for juveniles in 1997, possibly allowing them to be in better physical condition and better able to survive the post-fledging period. Similarly, Rohner and Hunter (1996) reported higher survival of juvenile Great Horned Owls during a peak in the population cycle of snowshoe hares (*Lepus americanus*). Higher survival may have occurred because juveniles were not as vulnerable to predation and disease as they were in years of low food availability, when mortality rates were significantly higher. The abundance of voles in 1997 may also have indirectly benefited juvenile Burrowing Owls. If potential predators were capable of meeting their energetic requirements by concentrating on voles, they may not have expended extra time or energy seeking other types of prey.

In 1997, the abundance of voles may also have influenced the dispersal of juvenile owls. Radio-tagged juveniles dispersed significantly farther from their nests during the post-fledging period in 1997 than in 1998, perhaps because young may have been better nourished because of the abundant food. Ferrer (1992, 1993) found that young Spanish Imperial Eagles (*Aquila adalberti*) in better physical condition tended to move farthest from their natal areas relative to those that were not as well nourished; however, Korpimäki and Lagerstrom (1988) found no relationship between food abundance and dispersal distance in juvenile Boreal Owls (*Aegolius funereus,* Tengmalm's Owl).

In 1998, an average year in terms of prey abundance (Poulin et al. 2001), almost half of the juvenile Burrowing Owls that fledged died before migration. Considering the high energetic costs and risks usually associated with migration, such a high premigratory mortality rate could have a considerable impact on population dynamics, suggesting that post-fledging mortality may be an important factor in the decline of this species in Saskatchewan.

ACKNOWLEDGMENTS

This research was funded by Wildlife Preservation Trust Canada and Science Horizons, with support from Saskatchewan Environment and Resource Management and from Saskatchewan Wetland Conservation Corporation. I thank R.G. Poulin, J. Skilnik, and R.A. Sissons for valuable help in the field. Special thanks to T.I. Wellicome, K. Scalise, M. Skeel, C. Palaschuk, E. Williams, and R. Fyfe. Reviews by B.A. Millsap, J. Pagel, and V.H. Vanegas improved the manuscript. I also gratefully acknowledge the participation and cooperation of the landowners who allowed access to their land.

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J. Raptor Res. 35(4):288–295

SYNCHRONOUS AND DELAYED NUMERICAL RESPONSES OF A PREDATORY BIRD COMMUNITY TO A VOLE OUTBREAK ON THE CANADIAN PRAIRIES

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ABSTRACT.—In 1997, meadow vole (*Microtus pennsylvanicus*) populations reached abnormally high levels in the grasslands of Saskatchewan. From 1996–98 on the Regina Plain, we studied the numerical responses of eight predatory birds to the meadow vole outbreak. Populations of Loggerhead Shrikes (*Lanius ludovicianus*) and American Kestrels (*Falco sparverius*) were unaffected by the high-vole year, but six other species exhibited significant numerical responses. Populations of Short-eared Owls (*Asio flammeus*) and Ferruginous Hawks (*Buteo regalis*) changed in synchrony with the availability of small mammals. Short-eared Owls were apparently nomadic, as they were common on our study area during the vole high, but were not observed the year before or the year after. In contrast, the Burrowing Owl (*Athene cunicularia*) population reached a historical low the year that voles were most abundant, but increased substantially in the following year. This was the only annual population increase observed for Burrowing Owls in our study area for at least a decade. Sightings of Red-tailed Hawks (*B. jamaicensis*), Swainson's Hawks (*B. swainsoni*), and Northern Harriers (*Circus cyaneus*) increased in the year of the vole outbreak and remained at elevated levels in the following year. Immature buteos were seldom seen before or after the vole peak, but during the vole peak, immatures were common, roosting together in large groups in fields.

KEY WORDS: *raptors; hawks; owls; Burrowing Owl;* Athene cunicularia; *Loggerhead Shrike; meadow vole; numerical response; grassland.*

Respuetas numericas subcronicas y retardadas de una comunidad depredadora de aves a una erupción de ratones de campo en las praderas canadienses

RESUMEN.—En 1997, las poblaciones del ratón de pradera (*Microtus pennsylvanicus*) alcanzaron niveles anormalmente altos en los pastizales de Saskatchewan. Desde 1996–98 en la Llanura de Regina, estudiamos las respuestas numéricas de ocho aves depredadoras a la proliferación de ratones de la pradera. Las poblaciones de Alcaudón Tonto (*Lanius ludovicianus*) y Cernicalos (*Falco sparverius*) no fueron afectadas por el año de alta abundancia de ratones, pero otras seis especies exhibieron respuestas numéricas significativas. Las poblaciones del Búho de Orejas Cortas (*Asio flammeus*) y del Gavilán ferruginoso (*Buteo regalis*) cambiaron sincrónicamente con la disponibilidad de los pequeños mamíferos. Los Búhos de Orejas Cortas aparentemente fueron nómadas, tanto así que fueron comunes en nuestra área de estudio durante la gran abundancia, pero no fueron observados el año anterior o al año siguiente. En contraste, la población del Búho Cavador (*Athene cunicularia*) alcanzó una baja histórica el año en que los ratones fueron mas abundantes, pero aumentaron sustancialmente al año siguiente. Este fue el único incremento poblacional anual observado en los Búhos Cavadores en nuestra área de estudio por lo menos en una década. Los avistamientos de Gavilanes de Cola Roja (*B. jamaicensis*), Gavilanes de Swainson (*B. swainsoni*) y Aguiluchos Norteños (*Circus cyaneus*) aumentaron en el año de explosión de ratones y permanecieron en niveles elevados al año siguiente. Los búteos inmaduros fueron vistos rara vez antes o después del pico de abundancia de ratones, pero durante el pico, los inmaduros fueron comunes, perchando juntos en grandes grupos en los campos.

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Table 1. Summary of search effort employed to survey birds of prey on the Regina Plain, Saskatchewan. Each day that a party recorded raptor sightings from a truck is considered one 'search day.' Thus, two trucks covering different routes on the same day were counted as two search days.

RANGE OF DATES	NO. OF SEARCH DAYS	TOTAL NO. OF HOURS SEARCHED	MEAN NO. OF HOURS PER SEARCH DAY	TOTAL DISTANCE SEARCHED (km)	MEAN DISTANCE PER SEARCH DAY (km)
19 Apr–13 Aug 1996	152	1101	7.2 ± 0.14	41 873	275 ± 7.3
21 Apr–19 Aug 1997	158	1028	6.5 ± 0.21	32 397	205 ± 7.2
14 Apr–20 Aug 1998	146	1005	6.9 ± 0.15	31 644	216 ± 5.7

Breeding densities of many raptor species vary from year to year because of annual fluctuations in their prey (Newton 1976). Such numerical responses of predators can be either in synchrony (S) with their prey, showing no obvious time lags, or delayed (D) by one or more years (Galushin 1974). Numerous examples of synchronous and delayed numerical responses to prey have been recorded for raptor species in a variety of habitats: in tundra, Rough-legged Hawk (*Buteo lagopus*) (S) (e.g., Virkkola 1992), Gyrfalcon (*Falco rusticolus*) (D) (Nielsen 1999), Short-eared Owl (*Asio flammeus*) (S) (Andersson 1981), and Snowy Owl (*Nyctea scandiaca*) (S) (Wiklund and Stigh 1986); in boreal, Northern Harrier (*Circus cyaneus*) (S) (Hamerstrom 1979), Northern Hawk-Owl (*Surnia ulula*) (S) (Rohner et al. 1995), Boreal Owl (*Aegolius funereus*) (S or D) (Korpimaki 1992), Great Horned Owl (*Bubo virginianus*) (D) (Rohner 1996), and Northern Goshawk (*Accipiter gentilis*) (S) (Doyle and Smith 2001); in semidesert, Harris' Hawk (*Parabuteo unicinctus*) (S), Red-backed Hawk (*Buteo polyosoma*) (S), and Black-chested Eagle (*Geranoaetus melanoleucus*) (S) (Jaksic et al. 1992); and in the tropics, Barn Owl (*Tyto alba*) (S) (Wilson et al. 1986).

Few studies have attempted to relate numerical changes of breeding raptors to annual food variation in grassland habitats (Schmutz and Hungle 1989, Steenhof et al. 1997). In the present study, we recorded patterns of inter-annual variation in population indices of eight species of predatory birds on the Regina Plain in southern Saskatchewan, Canada. We also estimated small mammal availability before, during, and after a meadow vole (*Microtus pennsylvanicus*) peak in the study area. Our effort and methods for obtaining population indices remained consistent within each species among years. However, given that the proportion of the population detected undoubtedly varied among species because of differences in size, behavior, and survey techniques (Millsap and LeFranc 1988), we made no attempt to compare population indices among species.

Four of our eight study species, including the endangered Burrowing Owl (*Athene cunicularia*, Wellicome and Haug 1995), are designated as a Species at Risk in Canada (Rothfels et al. 1999). Hopefully, an improved understanding of factors influencing populations of these species will also aid in their conservation.

METHODS

Study Area. This study was conducted in the grassland ecoregion of Saskatchewan (Harris et al. 1983), in an area roughly bounded by the cities of Regina (50°25'N, 104°39'W), Moose Jaw (50°23'N, 105°32'W), and Weyburn (49°41'N, 103°52'W). The study site encompassed 12 000 km^2 of predominantly cultivated land. Over 90% of the original grassland in the area has been converted to cropland (James et al. 1990). European settlement and farming in the region has resulted in roads, usually spaced by 3.2–6.4 km, running east-west and north-south in a grid across the study area.

Raptor Survey. To estimate the relative abundance of birds of prey (other than Burrowing Owls) in the study area, we counted Short-eared Owls, Northern Harriers, American Kestrels (*Falco sparverius*), Loggerhead Shrikes (*Lanius ludovicianus*), Ferruginous Hawks (*Buteo regalis*), Red-tailed Hawks (*B. jamaicensis*), and Swainson's Hawks (*B. swainsoni*) that we observed while driving in the study area each day. We also counted Prairie Falcons (*Falco mexicanus*), Merlins (*F. columbarius*), Great Horned Owls, and Golden Eagles (*Aquila chrysaetos*), but they were too rare for analysis. Field vehicles contained tally sheets on which investigators recorded observations of predatory birds, along with the number of km driven and hours worked each day (Hochachka et al. 2000). Young-of-the-year were not included for any species, and migrating individuals were excluded by the dates of our surveys (Table 1). Also, raptor species that migrate through, but do not breed in our study area (e.g., Rough-legged Hawk, Snowy Owl, and Gyrfalcon), were excluded from our analysis. Distant buteos that could not be identified to species were recorded as 'unknown buteos.' We did not record the sex or breeding status of birds, so non-breeding adults (e.g., second-year Red-tailed Hawks) were included in the overall abundance indices. Individuals may sometimes have been counted more than once per day because the same area was occasionally driven more than once in a day. However, such errors were likely consistent among years, so our method provided useful indices for comparing among-year population changes within species.

Our work was conducted during daylight hours, typically between 0900 H and 1800 H. Total search effort was similar among years (Table 1). To account for any variation in search effort, however, estimates of bird abundances were expressed as the mean number of individuals observed per 100 km traveled per census day. Among-year variation in these population indices was assessed for each species using one-way analysis of variance and significant differences were identified with post-hoc Tukey tests. All analyses were conducted with an alpha value of 0.05.

Burrowing Owl Census. Burrowing Owls were rarer than the other birds of prey in our study area, so we used a more intensive method to estimate changes in their population. Beginning in the second or third week of April (1996–98), all sites known to have Burrowing Owls in the previous 5 yr (James et al. 1997, Wellicome et al. 1997) were searched for signs of occupancy. We slowly drove or walked transects, spaced at ca. 25 m, through suitable nesting areas (i.e., non-cultivated fields), scanning each Richardson's ground squirrel (*Spermophilus richardsonii*) or badger (*Taxidea taxus*) burrow for signs of owls, owl pellets, or whitewash. In addition to our searches, the Operation Burrowing Owl program in Saskatchewan had a toll-free telephone number that other biologists and members of the general public were encouraged to use to report Burrowing Owl sightings (Skeel et al. 2001). We investigated each reported sighting within our study area.

We are confident that our census was accurate because nesting pastures were small and work on Burrowing Owls had been ongoing since 1987 in the area (James et al. 1997, Wellicome et al. 1997). However, as an accuracy check, we randomly chose five of the 28 townships (each 9.6 km × 9.6 km) that contained owls in 1995, and searched all grassland fragments and roadside ditches (regardless of whether the sites had any previous records of owls) within this subset of townships in 1996. We searched all suitable habitat within these townships by driving slowly along ditches and walking transects in pastures and other grasslands. No new owls were found using this intensive search, suggesting that the estimated population size obtained from our usual census technique was close to 100% of the actual population (see Wellicome et al. 1997 for details).

Small Mammals. Burrowing Owls are generalist hunters that capture prey species in the same proportions as are available in the environment (Green et al. 1993, Plumpton and Lutz 1993, Silva et al. 1995, but see Jaksic et al. 1992). On the Regina Plain study area, vertebrate prey made up between 85–97% of total prey volume measured in food pellets annually during the breeding season (Wellicome 2000). We obtained an index of small mammal availability by counting the number of small mammals cached inside Burrowing Owl nests, as average annual cache size has been shown to reflect annual relative prey abundance in our study area (measured by small mammal trapping over a 4-yr period; Wellicome 2000). To determine cache sizes, we opened all Burrowing Owl nests that were in artificial nest boxes. Artificial nest boxes allowed us to access nest chambers to count and mark all stored prey items without disturbing the physical structure of the nest (Wellicome et al. 1997, Wellicome 2000). For analyses, we used prey-cache data collected up until 2 wk after the first egg was laid in each nest because this laying period had the highest rate of prey caching within each season (Wellicome 2000). Cache size was measured as the mean number of prey items found in each nest, provided the nest had been visited at least twice during pre-laying and laying. The mean of all nests was then calculated to obtain an index of relative abundance of small mammals in the study area for each year between 1992–98.

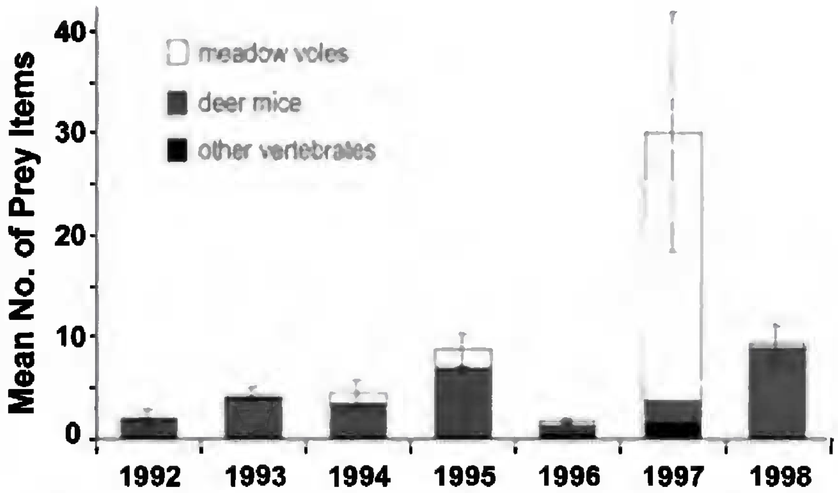

Figure 1. Mean number of vertebrates cached by Burrowing Owl pairs in each of 7 yr. Values were calculated for each pair by averaging the number of prey counted in nest stores during checks in both the pre-laying and laying periods. Bars indicate annual means of all vertebrate prey cached and error bars show SE. 'Other vertebrate prey' include sagebrush voles, house mice, shrews, passerines, and tiger salamanders. Prey-cache data were collected from 13, 24, 16, 26, 17, 18, and 17 pairs in 1992–98, respectively (adapted from Wellicome 2000).

RESULTS

Almost all cached vertebrate prey were either deer mice (*Peromyscus maniculatus*) or meadow voles. Other vertebrate prey included sagebrush voles (*Lemmiscus curtatus*), house mice (*Mus musculus*), shrews (*Sorex* spp.), passerines, and tiger salamanders (*Ambystoma tigrinum*). Excluding 1997, a mean of 70% (range = 40–87%) of the vertebrate prey items found in Burrowing Owl nests were deer mice, and only 19% (range = 7–32%) of prey items were meadow voles (Fig. 1). In 1997, general field observations and snap-trapping data (Wellicome 2000, Sissons et al. 2001) suggested that the small mammal population reached extremely high levels. Such a high abundance of small mammals

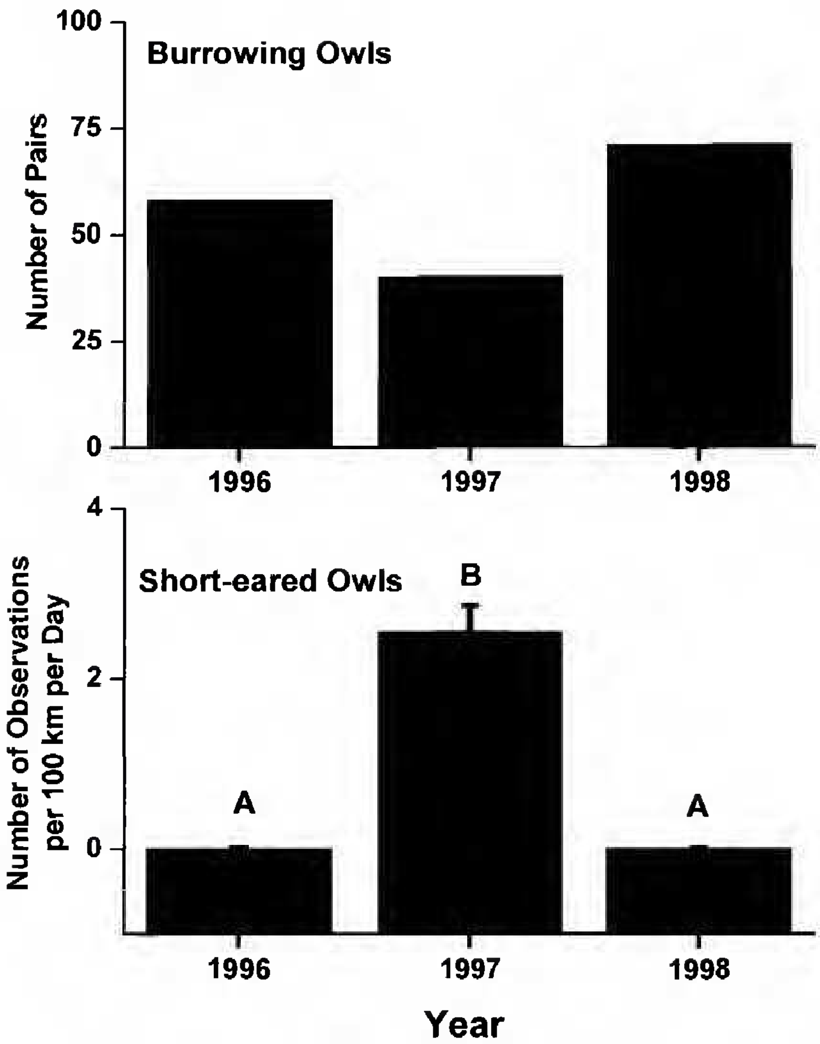

Figure 2. Total number of Burrowing Owl pairs on the study area, and Short-eared Owl population index ([mean No./100 km/search day] ± SE) in three separate years. The Burrowing Owl population had a delayed response to the high abundance of small mammals in 1997, but the Short-eared Owl population had a synchronous response. For Short-eared Owls, results from Tukey tests are shown with letters above each bar; differing letters indicate that among-year differences in observation rates were significant.

was evidently a rare occurrence, as populations had not been this plentiful since 1969 (Houston 1997). In 1997, 87% of cached prey items were meadow voles, making the mean total number of prey items per nest between three and 16 times higher in 1997 than in the other years (Fig. 1).

Data have been collected on the population size of Burrowing Owls in a portion of our study area since 1987 and there was a decline in every year except 1998 (James et al. 1997, Wellicome et al. 1997). The only recorded increase in the number of Burrowing Owls was between 1997–98 (Fig. 2) and the fewest Burrowing Owls in the past decade occurred in 1997, the year of the meadow vole outbreak.

Neither Loggerhead Shrikes ($F = 0.08$, df = 2, $N = 453$, $P = 0.93$) nor American Kestrels ($F = 1.7$, df = 2, $N = 453$, $P = 0.17$) showed significant population responses to the 1997 vole increase. The mean number of individuals (±SE) observed per 100 km per search-day from 1996–98, were 0.17 ± 0.03, 0.16 ± 0.03, and 0.18 ± 0.03 for shrikes, and 0.15 ± 0.03, 0.09 ± 0.03, and 0.17 ± 0.04 for kestrels, respectively.

There was a highly-significant difference in the number of Short-eared Owls observed among years ($F = 68.4$, df = 2, $N = 453$, $P < 0.001$; Fig. 2). In both 1996 and 1998 (years with normal small mammal populations), we observed this species on only two occasions; whereas, in 1997 (the peak vole year), we recorded a total of 604 observations of this species.

There was significant annual variation in the number of Swainson's Hawks ($F = 56.92$, df = 2, $N = 453$, $P < 0.001$), Red-tailed Hawks ($F = 29.1$, df = 2, $N = 453$, $P < 0.001$), Ferruginous Hawks ($F = 13.7$, df = 2, $N = 453$, $P < 0.001$), and total buteos (including unknown; $F = 49.897$, df = 2, $N = 453$, $P < 0.000$) observed per 100 km per day. For each of the three species, there were significantly more observations during the year of the vole outbreak (Fig. 3). In the year following the vole outbreak, when prey numbers returned to a normal level, both Swainson's and Red-tailed Hawk populations remained significantly higher than they were in the year prior to the vole outbreak. However, observations of Ferruginous Hawks did not remain elevated in the year following the vole peak. For all buteos combined (unidentified, Red-tailed, Swainson's, and Ferruginous Hawks), there were eight times more observations in 1997 (3413), and four times more observations in 1998 (1667), than there were in 1996 (416). Although the numbers of adult vs. immature birds were not recorded, there was an obvious increase in the frequency of immature buteos in 1997. Most observations of buteos in 1997 were of 1-yr-old Swainson's and Red-tailed Hawks, but in 1996 and 1998 almost all observations were of adult, breeding birds (pers. observ.).

There was significant annual variation in the number of Northern Harriers observed per 100 km per day ($F = 51.3$, df = 2453, $P < 0.001$; Fig. 3). Harriers were much more abundant in 1997 than in 1996, but did not decrease in 1998 to 1996 levels.

DISCUSSION

Two of the eight avian predators in this study showed no significant numerical response to the

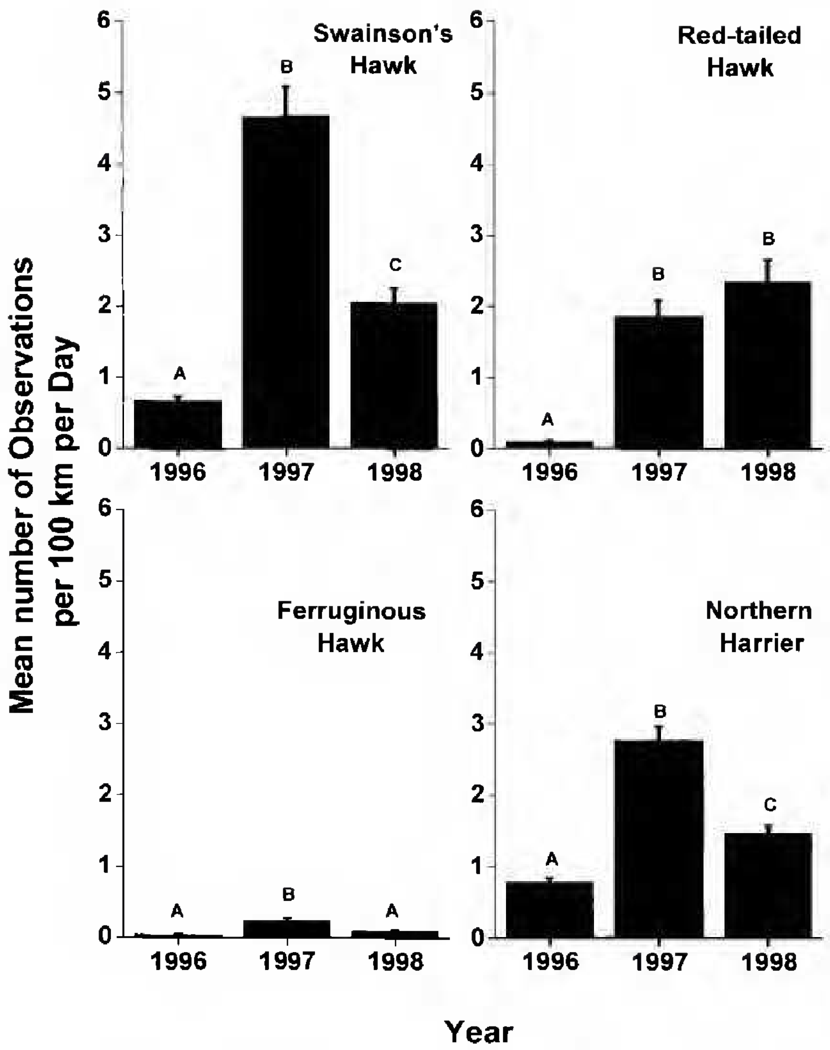

Figure 3. Population indices ([mean No./100 km/search day] ± SE) for Swainson's Hawks, Red-tailed Hawks, Ferruginous Hawks, and Northern Harriers. All four species exhibited a synchronous response to the high abundance of small mammals in 1997 and all species except the Ferruginous Hawk were higher in 1998 than in 1996. Results from Tukey tests are shown with letters above each bar; differing letters indicate that among-year differences in observation rates were significant. Note that patterns of change in population indices among years can be compared, but that indices should not be compared among species, as detectability likely differed among species.

small mammal high in 1997; populations of Loggerhead Shrikes and American Kestrels remained stable over all three survey years. This lack of response might have been an artifact of the relatively small populations of these two species in our study area. Alternatively, it is possible that these two species relied heavily on prey items other than small mammals. For example, they may have fed predominantly on insects. Another possibility is that, rather than food supply, availability of nesting sites limited their populations. This explanation might be plausible for kestrels, as they are obligate secondary-cavity nesters (Bent 1938), but seems less likely for shrikes, as they construct their own stick nests in shrubs or small trees (Yosef 1996).

The remaining six avian predators in this grassland study showed significant numerical responses to the vole high in 1997. In general, local increases in bird populations in response to elevated prey numbers can result from increased reproductive output *in situ* and/or immigration from peripheral populations (Solomon 1949). The numerical response of the Short-eared Owl to prey can undoubtedly be attributed to immigration because Short-eared Owls were rare on the study area in 1996, but suddenly became very common in 1997 with the increase in voles. Such synchronous responses are characteristic of species with nomadic lifestyles (Galushin 1974). In concordance with our results in the grasslands, the Short-eared Owl has been described as nomadic also in boreal (Korpimaki and Norrdahl 1991) and tundra habitats (Andersson 1981). The species' specialized diet, simple nest-site requirements, and large clutch size seem to make it particularly well suited to a lifestyle of nomadism (Holt and Leasure 1993).

Although the Burrowing Owl shares some of these general characteristics with the Short-eared Owl, it exhibited an opposite response to the prey high. Burrowing Owls in our study were at their lowest during the vole peak but increased in the subsequent year (Fig. 2). The 1-yr delay in the population's response to the vole outbreak suggests that these owls are not nomadic, as they do not search actively for nesting sites based on the current availability of prey in an area, at least not at a large geographic scale. Given that the species is not nomadic then, other mechanisms must explain its observed numerical response to the prey high. Although clutch size was no higher for Burrowing Owls during the vole high in 1997, both nestling survival and fledging success were substantially elevated in that year compared to other years (Wellicome 2000). In addition, post-fledging survival was significantly higher in 1997 than it was in years following (Todd 2001) or preceding the vole high (Clayton 1997). Furthermore, the percent of fledglings from 1997 that returned to breed in the population in 1998 was twice that of returns from other years (R. Poulin, T. Wellicome, and L. Todd unpubl. data). These factors, alone or in combination, seem to have contributed to the delayed numerical response exhibited by Burrowing Owls to the vole high. Interestingly, the only study other than ours to examine the reaction of a Burrowing

Owl population to a prey high, showed that owls in a Chilean semi-desert also exhibited a delayed numerical response (Jaksic et al. 1997).

Unlike Short-eared Owls, Burrowing Owls consume a wide variety of prey items, and their diet often changes depending on the availability of prey in the environment (Green et al. 1993, Plumpton and Lutz 1993, Silva et al. 1995, Jaksic et al. 1992). Thus, Burrowing Owls are not overly reliant on any one type of prey, and can switch to take advantage of peaks in several prey species (Fig. 1).

Ferruginous Hawks showed a synchronous response to the vole outbreak, reaching their highest relative population size in 1997. A nomadic tendency has been suggested for breeding populations of this species (Schmutz and Hungle 1989, Bechard and Schmutz 1995). However, unlike Short-eared Owls, Ferruginous Hawks did not appear to react strongly to the voles and remained an uncommon species through the course of our study (Fig. 3). We did not examine reproduction, but if Ferruginous Hawks fledged more young in 1997 than in other years, we might not expect to see an increase in the breeding population until 1999 when those fledglings reached breeding age (Bechard and Schmutz 1995). Alternatively, perhaps these hawks specialized on Richardson's ground squirrels in our area, as has been noted in other studies (e.g., Schmutz and Hungle 1989), in which case Ferruginous Hawks would be expected to show little reaction to vole populations.

Populations of Red-tailed and Swainson's Hawks showed elements of both synchronous and delayed responses. We noted, though, that most of the hawks in the high-food year were non-breeding, immature birds. It was common in the 1997 breeding season to see dozens of immature buteos roosting communally in fields. In 1996 and 1998, the only similar densities of hawks occurred when adults congregated to feed near tractors that were tilling fields, and those observations were comparatively rare. This raises the intriguing possibility that different age-classes of these species might use different strategies for distributing themselves geographically with respect to prey. That is, adults may choose to be faithful to nesting sites (which may be limited), returning to the same territories each year regardless of prey; whereas, immature buteos may opt for a nomadic lifestyle, searching at a large geographic scale and settling in areas with high prey availability. In this scenario, immature hawks could specialize on hunting voles wherever they were most plentiful on the landscape; whereas, adults would be forced to be generalists, eating whatever prey was available in their breeding territories each year. Further research is needed to test this hypothesis because, although studies suggest that adult breeders in these species are generalist predators faithful to their breeding sites, little is known about the ranging behavior of immature hawks (Preston and Beane 1993, England et al. 1997).

The above scenario does not explain why Red-tailed and Swainson's Hawk numbers were higher in 1998 than they were in 1996. This delayed partial response to the vole high could have been caused by an increase in adult survivorship, by an increase in breeding fidelity, or by a number of immature birds from 1997 returning to breed in the study area in 1998.

Northern Harriers showed a synchronous increase with the meadow vole peak in our study. This is in agreement with the results of a long-term study in Wisconsin, which found that harriers fluctuated in synchrony with meadow voles during a 16-yr period (Hamerstrom 1979). However, similar to the populations of Swainson's and Red-tailed Hawks, the population of Northern Harriers remained at higher levels in 1998 than in 1996, suggesting that perhaps they experienced high productivity in 1997 and/or high survivorship and site fidelity over the winter of 1997–98. Northern Harriers commonly feed on meadow voles, but they also supplement their diet with several other prey species (MacWhirter and Bildstein 1996). Unlike Short-eared Owls, the more generalized diet of harriers likely allows them to remain on the Regina Plain as a resident population in years of more moderate vole abundance.

ACKNOWLEDGMENTS

We wish to acknowledge the efforts of R. Sissons, J Skilnick, D. Grier, and D. Junor for their thoroughness in helping watch the skies. We are grateful to C.S. Houston, N.L. Brown, and D.K. Rosenberg for critical reviews of this manuscript, and thank M. Brigham, D. Schock, and C. Aldridge for helpful comments on earlier drafts We thank K. Scalise for enabling this research through her fund-raising and coordinating efforts. Financial and in-kind support for this project was provided by World Wildlife Fund, Saskatchewan Environment and Resource Management, Foothills Pipe Lines, TransGas, Trans-Canada PipeLine, InterProvincial Pipe Lines Inc. Environmental Youth Corps Canada, Wildlife Preservation Trust Canada, Nature Saskatchewan, and Operation Burrowing Owl.

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J Raptor Res. 35(4):296–303

NESTING ECOLOGY OF BURROWING OWLS OCCUPYING BLACK-TAILED PRAIRIE DOG TOWNS IN SOUTHEASTERN MONTANA

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Abstract.—Detailed investigations of the relationship between Burrowing Owls (*Athene cunicularia*) and black-tailed prairie dogs (*Cynomys ludovicianus*) are rare, but such information is necessary to manage the population declines of owls reported throughout much of the western United States. In 1998 we studied nest-site selection, productivity, and food habits of Burrowing Owls breeding on prairie dog towns in southeastern Montana. We located 13 breeding pairs, seven of which nested on private land. Nesting density (1 pair/110 ha) on prairie dog towns was low compared to densities in other regions. Few habitat characteristics differed between nest sites and random points, but power in statistical tests was low. Nesting density and habitat use suggested the population of owls was well below carrying capacity. Productivity was 2.6 young/pair. Owls fed on invertebrates (mainly grasshoppers and beetles), mammals (mice and voles), birds (blackbirds and buntings), and amphibians (frogs). Plague (*Yersinia pestis*), poison, and habitat conversion have fragmented prairie dog habitat and potentially threaten owl persistence in our study area.

Key Words: *Burrowing Owl;* Athene cunicularia; *black-tailed prairie dog;* Cynomys ludovicianus; *plague;* Yersinia pestis; *food habits; habitat selection; Montana.*

Ecológia del anidamiento de Búhos Cavadores ocupando poblados de perros de la pradera de cola negra en el sudeste de Montana

Resumen.—Investigaciones detalladas de la relación entre Búhos Cavadores (*Athene cunicularia*) y perros de la pradera de cola negra (*Cynomys ludovicianus*) son raros, pero tal información es necesaria para manejar el descenso de la población de búhos reportado en la mayoría del occidente de los Estados Unidos. En 1998 nosotros estudiamos la selección de sitios nido, productividad, y hábitos alimenticios de Búhos Cavadores reproduciéndose en colonias de perros de la pradera en el sudeste de Montana. Localizamos 13 parejas reproductoras, siete de las cuales anidaban en terrenos privados. La densidad de anidamiento (1 pareja/110 ha) en los poblados de perros de la pradera fue baja en comparación a densidades de otras regiones. Pocas características del hábitat diferían entre los sitios nido y puntos al azar, pero el poder de las pruebas estadísticas fue bajo. La densidad de anidamiento y el uso de hábitat sugiere que la población de búhos estaba bien por debajo de la capacidad de carga. La productividad fue 2.6 jóvenes/pareja. Los búhos se alimentaron de invertebrados (principalmente saltamontes y escarabajos), mamíferos (ratones y campañoles), aves (mirlos y verderones), y anfibios (ranas). La peste (*Yersinia pestis*), el veneno y la transformación del hábitat ha fragmentado el hábitat de los perros de la pradera y potencialmente ha puesto bajo amenaza la persistencia de los búhos en nuestra área de estudio.

[Traducción de Victor Vanegas y César Márquez]

The recent finding that the petition to list the black-tailed prairie dog (*Cynomys ludovicianus*) under the U.S. Endangered Species Act is "warranted but precluded" draws national attention to the status and management of a declining species subjected to poisoning campaigns, recreational shooting, and introduced plague (*Yersinia pestis*). Decreases of prairie dog populations and their

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habitat are thought to be responsible for similar declines of closely associated species (Miller et al. 1994, Samson and Knopf 1994), most notably the black-footed ferret (*Mustela nigripes*) and mountain plover (*Charadrius montanus*). Burrowing Owls (*Athene cunicularia*) in the Great Plains south of Canada also rely on prairie dog habitat (Butts and Lewis 1982, Plumpton and Lutz 1993a, Desmond et al. 1995), and many states report recent declines in owl abundance (James and Ethier 1989, Marti and Marks 1989, James and Espie 1997).

Although Burrowing Owls nest extensively in prairie dog burrows, few studies have reported habitat characteristics important in nest-site selection or factors influencing owl density within prairie dog towns. In Colorado, differences between nest burrows and random burrows in surrounding burrow density, town size, and distance to road varied from year to year (Plumpton and Lutz 1993a); however, owls favored areas with lower vegetation than was available at random on prairie dog towns. In Nebraska, owls nested in loose colonies within larger prairie dog towns, but spaced themselves randomly within smaller towns (Desmond et al. 1995). Density of prairie dog burrows did not affect spacing patterns of nesting owls, and a positive relationship existed between town size and number of nesting pairs (Desmond and Savidge 1996).

Plague, poisoning, and habitat conversion have reduced and fragmented prairie dog towns across the Great Plains, including Montana (Flath and Clark 1986), but how these processes affect nest-site selection and population ecology of Burrowing Owls remains unknown. In 1998 we initiated a study in southeastern Montana to elucidate nest-site selection of Burrowing Owls occupying black-tailed prairie dog towns. We also estimated productivity and quantified food habits. We selected a study area previously mapped for prairie dogs because presence/absence of Burrowing Owls had been recorded during visits (R. Richardson, D. Tribby, K. Wittenhagen, Jr. unpubl. data). Thus, some data were available to determine the population trend of owls.

STUDY AREA AND METHODS

The study area in southeastern Montana (Custer and Prairie counties; 46°44′N, 105°38′W) encompassed approximately 400 km^2, of which 1425 ha (3.6%) was occupied by black-tailed prairie dogs. We surveyed the prairie dog complex within the Custer and Harris Creek watersheds, areas being considered for black-footed ferret reintroduction. The badland topography was gently rolling to flat (elevation 680–865 m). Vegetation was dominated by grasses (*Agropyron smithii*) and shrubs (*Artemisia tridentata* and *A. cana*). Riparian areas supported scattered cottonwood (*Populus tremuloides*) and willow (*Salix* spp.), while open stands of ponderosa pine (*Pinus ponderosa*) and juniper (*Juniperus scopulorum*) dominated hilly terrain. Climate was semi-arid. The study area was an even mixture of public (federal and state) and private land that supported livestock grazing. Recreational shooting of prairie dogs occurred year round, but was concentrated during spring and early summer.

Beginning in mid-May 1998, we used spotting scopes (15–45×) and binoculars (10×) to survey prairie dog towns for Burrowing Owls. We made no attempt to search for owls off of prairie dog towns. We scanned towns from a vehicle or on foot, concentrating effort in early morning (0500–1000 H) or late afternoon (1700–2200 H), the daytime periods when owls are most active and visible (Haug and Oliphant 1990). Presence of territorial pairs, whitewash, cast pellets, molted feathers, and prey remains were used to identify nest burrows. We used a GPS receiver (Garmen XL 12) to plot the locations of nest burrows on USGS 7.5 min topographic maps. Individual towns were visited repeatedly (every 2 wk) throughout the field season (May–August) to minimize the possibility of overlooking secretive or non-breeding owls and to monitor nesting success.

At nest burrows (N = 13), we measured elevation (nearest m with a GPS receiver) and percentage slope with a clinometer. From the nest burrow, we used a tape to measure distance to the nearest active and inactive prairie dog burrows (±0.05 m), nearest edge of the prairie dog town (±0.5 m), and nearest road (±0.5 m). We also counted active (presence of fresh diggings and/or scat) and inactive prairie dog burrows within a 30-m radius of the nest burrow (0.28 ha circle) to index prairie dog activity (Biggens et al. 1993). Size of prairie dog towns was obtained from habitat mapping with a GPS receiver conducted from July–September 1996 (K. Wittenhagen, Jr. and D. Tribby unpubl. data). We used a GPS receiver to measure distance (±50 m) from the nest burrow to the nearest neighboring nest burrow.

We also measured these same habitat variables at 13 burrows selected haphazardly from prairie dog towns not occupied by nesting owls. We selected burrows by dividing randomly selected prairie dog towns into progressively smaller quadrants bisected by the cardinal directions (numbered 1–4, chosen using a random numbers table). The number of quadrants required to narrow down to a single potential nest burrow depended upon the size of the prairie dog town. We picked only those burrows with openings large enough for nesting owls.

Terminology describing reproductive success and productivity of Burrowing Owls followed Steenhof (1987). successful pairs fledged at least one young, and productivity estimates included both successful and failed pairs We assumed every owl pair attempted to breed (i.e., laid eggs). Multiple visits (10–20) to individual nest sites throughout the breeding season permitted accurate determination of nesting success (young fledged per pair). We estimated nesting chronology from age of emerged young based on plumage (Priest 1997), assuming an in-

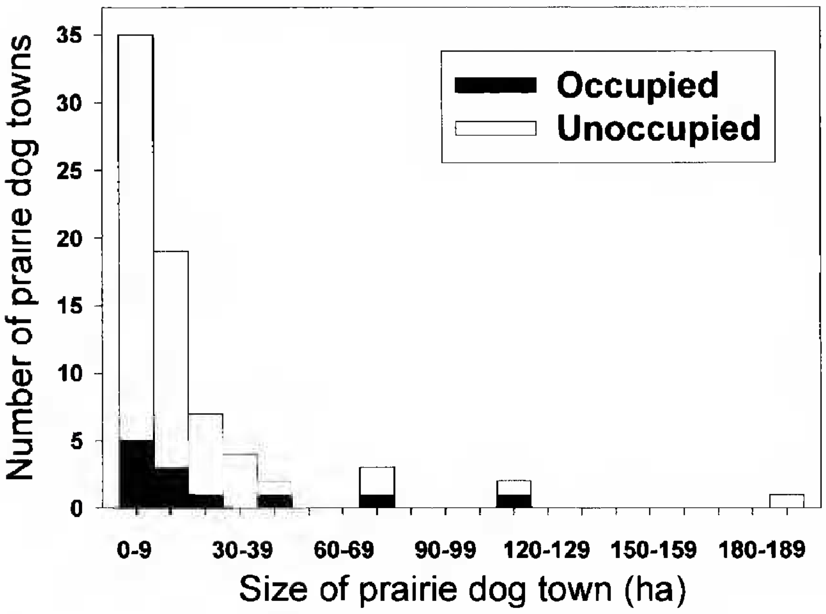

Figure 1. Size (ha) of black-tailed prairie dog towns occupied and unoccupied by Burrowing Owls in southeastern Montana, 1998.

cubation period (first egg to first hatch) of 30 d and fledging at 40 d (Haug et al. 1993).

We collected pellets and prey remains opportunistically from May–August while visiting nest sites and surrounding perching and feeding areas. Entomologists at Montana State University, Bozeman, used a dissecting scope (6.4–10×) to sort and identify invertebrate remains to family, and relied on museum specimens and Borror et al. (1989) for classification to genus. To save space, we have presented invertebrate taxa to only the family level. We checked remains of vertebrate prey against pellet contents collected during subsequent visits to the same nests to minimize duplication. We used a dissecting scope (7–30×) to identify vertebrate prey, and relied on museum specimens and Hoffman and Pattie (1968) for classification to species. Number of both invertebrate and vertebrate prey were determined conservatively by presence of diagnostic body parts (e.g., legs, mandibles, skulls). We calculated percentage biomass using estimates from Marti (1974), Rodriguez-Estrella (1997), and museum specimens.

We log transformed data prior to analyses (SPSS 1998) to achieve normal distributions (Kolmogorov-Smirnov test) and homogeneity of variances (Levene's test). However, we have presented untransformed data ($\bar{x}$ ± SE) in this paper to facilitate interpretation. Because of the relatively small number of nesting pairs (N = 13) and concerns of low statistical power, we opted to reduce Type II errors by assigning statistical significance at $P \leq 0.10$ when comparing habitat variables between occupied and random sites.

RESULTS

Prairie dog towns on our study area averaged 19.5 ± 3.6 ha (range = 0.4–198.3 ha, N = 73). Most occupied prairie dog habitat surveyed was on private land (65%), followed by federal (30%) and state (5%) lands. Prairie dog towns averaged 11.0 ± 1.9 ha on private lands (N = 30) and 17.3 ± 5.3 ha on public lands (N = 19; t = 0.64, df = 47, P = 0.53).

Burrowing Owls nested on 12 of 73 (16%) prairie dog towns that we surveyed in 1998. We found 13 breeding pairs of Burrowing Owls on ca. 1425 ha (1 pair/110 ha) of prairie dog towns within the 400 km^2 study area. No single adult owls were observed. Size of prairie dog towns did not differ between towns occupied by owls and towns unoccupied by owls (t = 1.24, df = 71, P = 0.22; Fig. 1). Burrowing Owls neither preferred nor avoided nesting on prairie dog towns subjected to recreational shooting (χ^2 = 0.00, df = 1, P = 1.00) or to grazing (χ^2 = 0.16, df = 1, P = 0.69). Seven pairs nested on private land, with three pairs each on federal and state land.

Most habitat characteristics did not differ for occupied Burrowing Owl nest sites and random points (Table 1). Occupied nests were closer to ac-

Table 1. Habitat characteristics ($\bar{x}$ ± SE) of Burrowing Owl nest sites (N = 13) and random sites (N = 13) on black-tailed prairie dog towns in southeastern Montana, 1998.

HABITAT VARIABLE	OCCUPIED SITE	RANDOM SITE	t	P
Elevation (m)	749 ± 51	752 ± 58	0.15	0.88
Percentage slope	2.6 ± 0.5	2.3 ± 0.4	0.27	0.79
Nearest active burrow (m)	14.6 ± 7.1	21.8 ± 6.4	1.81	0.08
Nearest inactive burrow (m)	6.7 ± 1.9	7.7 ± 2.8	0.68	0.50
Number of active burrows	11 ± 2	9 ± 2	0.74	0.47
Number of inactive burrows	32 ± 3	30 ± 3	0.56	0.58
Distance to town edge (m)	111 ± 36	73 ± 17	0.85	0.40
Town size (ha)	27.3 ± 10.1	25.4 ± 7.1	0.96	0.35
Nearest road (m)	227 ± 98	280 ± 110	1.29	0.21
Nearest neighbor (km)	2.2 ± 0.5	3.3 ± 0.7	1.28	0.21

Table 2. Prey of Burrowing Owls based on remains found at nest and perch sites on black-tailed prairie dog towns in southeastern Montana, 1998. Prey are expressed in number of items (*N*), percentage frequency, and percentage biomass. Unidentified items were not included in biomass estimates. Invertebrates were identified to family, vertebrates to genus or species.

Taxon	*N*	Percent Frequency	Percent Biomass
Chilopoda			
Scolopendromorpha	1	<1	<1
Arachnida			
Scorpiones	2	<1	<1
Araneae	6	<1	<1
Non-insect arthropod	2	<1	<1
Insecta			
Odonata			
Family undetermined	1	<1	
Orthoptera			
Acrididae	311	26	9
Gryllacrididae	4	<1	<1
Gryllidae	8	<1	<1
Hemiptera			
Belostomatidae	3	<1	<1
Reduviidae	1	<1	<1
Coleoptera			
Carabidae	337	28	3
Silphidae	72	6	<1
Hydrophilidae	3	<1	<1
Histeridae	1	<1	<1
Scarabaeidae	127	11	<1
Elateridae	1	<1	<1
Tenebrionidae	81	7	<1
Meloidae	1	<1	<1
Cerambycidae	42	3	<1
Chrysomelidae	5	<1	<1
Curculionidae	12	1	<1
Diptera			
Asilidae	1	<1	<1
Muscoidea	1	<1	<1
Lepidoptera			
Sphingidae	1	<1	<1
Hymenoptera			
Sphecidae	7	<1	<1
Eumenidae	4	<1	<1
Formicidae	16	1	<1
Undetermined Hymenoptera	2	<1	
Amphibia			
Rana pipiens	28	2	10
Scaphiopus bombifrons	2	<1	<1
Aves			
Sturnella neglecta	18	1	25
Calamospiza melanocorys	22	2	11
Undetermined	1	<1	
Mammalia			
Spermophilus richardsonii	6	<1	18
Perognathus fasciatus	4	<1	<1
Peromyscus spp.	36	3	11
Onychomys leucogaster	2	<1	1
Microtus spp.	12	1	8
Zapus hudsonius	2	<1	<1
Unknown rodents	16	1	
Total	1202	100	100

tive prairie dog burrows than were random points. Neither number of active prairie dog burrows nor total number of burrows (inactive + active) correlated with town size ($P > 0.30$, $N = 26$). Statistical power was 0.35 for each of the two contrasts with low and nonsignificant *P*-values (i.e., nearest road and nearest neighbor).

Burrowing Owls produced 2.6 ± 0.4 young/pair ($\bar{x} \pm$ SE, $N = 13$ pairs). Twelve pairs (92%) each produced at least one fledgling. One pair failed for unknown reasons. Productivity did not correlate with number of active or inactive prairie dog burrows ($P > 0.30$, $N = 13$) within a 30-m radius of the nest. Productivity also did not correlate with size of prairie dog towns ($P = 0.57$, $N = 13$). Owls nesting on prairie dog towns subjected to recreational shooting ($N = 6$) had productivity similar to those nesting pairs not exposed to shooting ($N = 7$) (2.3 young/pair versus 2.9 young/pair, respectively; $t = 0.65$, df = 1, $P = 0.54$). By backdating from young of known age ($N = 7$ nests), we estimated a $\bar{x}$ laying date of 20 May (±1 d), $\bar{x}$ hatching date of 19 June (±1 d), and $\bar{x}$ fledging date of 29 July (±1 d).

We identified 1053 invertebrate and 149 vertebrate prey remains (Table 2). The most common invertebrate prey were grasshoppers (Orthopotera) and beetles (Coleoptera). Amphibian prey included northern leopard frogs (*Rana pipiens*) and plains spadefoot (*Scaphiopus bombifrons*). Only two species of birds were taken: Lark Bunting (*Cala-*

mospiza melanocorys) and Western Meadowlark (*Sturnella neglecta*). Mice (*Peromyscus* spp.) and voles (*Microtus* spp.) were the most common mammalian prey. Most important prey items in terms of biomass were meadowlarks (25%), mice + voles (20%), and Richardson's ground squirrels (*Spermophilus richardsonii*; 18%).

DISCUSSION

Burrowing Owl Use of Prairie Dog Towns. Two observations suggested the Burrowing Owl population was well below carrying capacity of nesting habitat on black-tailed prairie dog towns within our study area. First, density of Burrowing Owls (1 pair/110 ha) was low compared to densities in Oklahoma (1 pair/0.19 ha, Butts 1971), and $\bar{x}$ nearest-neighbor distance on our study area (2.2 km) greatly exceeded that in Nebraska (0.11–0.13 km, Desmond and Savidge 1996). In fact, only one prairie dog town supported more than one pair of owls. Second, the habitat characteristics we measured did not differ between nest sites and random points. Prairie dog towns unoccupied by owls were vacant apparently for reasons other than habitat suitability, perhaps indicating an owl population in decline (Schmutz 1997). However, conclusions regarding habitat suitability remain preliminary because some comparisons lacked adequate statistical power to detect differences between occupied and random sites.

The only habitat attribute that appeared to differ between nests and random points was distance to the nearest burrow occupied by prairie dogs, which was less for nest sites. Why owls nested near active prairie dog burrows remains unknown, but two previously noted patterns imply an anti-predator benefit. Owls nesting in areas of highest burrow density in Nebraska suffered less badger (*Taxidea taxus*) predation than did other nesting owls (Desmond et al. 2000). Badger predation on black-tailed prairie dogs also correlated positively with town size in Wyoming (Campbell and Clark 1981). Density of prairie dog burrows did not correlate with town size in both Wyoming and southeastern Montana. The relationships between badger predation and (1) burrow density and (2) town size imply that highest predation of owls should occur on large towns with low burrow density, assuming badger predation on owls occurs under the same conditions as predation on prairie dogs.

Prairie dog towns occupied by Burrowing Owls in southeastern Montana were half the size of occupied towns in Nebraska (Desmond et al. 1995). Burrow densities of prairie dog towns in southeastern Montana and Colorado (Plumpton and Lutz 1993a) were similar, but were 3× higher than in Nebraska (Desmond et al. 1995). Therefore, prairie dog towns occupied by nesting owls in southeastern Montana were relatively small and active, habitat conditions that should have minimized the probability of badger predation. Badger predation of owls did not occur during our study, supporting this hypothesis.

Historically, Burrowing Owl occupancy of prairie dog towns on our study area was highest in 1978–79 (27%, 15 of 55 towns; C. Knowles pers. comm.), intermediate in 1991 (14%, nine of 66 towns; R. Richardson and D. Tribby unpubl. data), and lowest in 1996 (4%, three of 73 towns; K. Wittenhagen, Jr. and D. Tribby unpubl. data). We recorded an increase to 16% (12 of 73 towns) occupancy in 1998. Fluctuating population size of Burrowing Owls over the past 20 yr may have reflected the impact of plague. Plague was first confirmed on our study area in 1986, and by the late 1980s had significantly reduced prairie dog populations in southeastern Montana (C.J. Knowles unpubl. data). Owl occupancy should lag behind fluctuating prairie dog populations (which it did) if towns decimated by plague provide nesting habitat for 3–4 yr before inactive burrows collapse or fill in with soil (Butts and Lewis 1982, Desmond et al. 2000).

In this study area, rodents and birds composed most of the Burrowing Owl diet by percent biomass, whereas insects dominated percent frequency. Owls nesting on prairie dog towns in Colorado and Wyoming exhibited similar prey use (Marti 1974, Thompson and Anderson 1988, Plumpton and Lutz 1993b). Use of prey varied seasonally, as mammalian prey were most important to owls early in the nesting period before insects became available (Marti 1974, Green and Anthony 1989, Schmutz et al. 1991). Owls appeared to forage for mammals mostly at night and concentrated on insects during daylight. In Saskatchewan home range size decreased significantly once insects became abundant (Haug and Oliphant 1990).

Management Implications. Productivity and juvenile and adult survivorship act in concert to determine the trend of Burrowing Owl populations (James et al. 1997, Johnson 1997, Clayton and Schmutz 1999). Some of the mechanisms that affect demography included habitat availability, predation, and food availability. Productivity and population size of Burrowing Owls in southeastern Montana during 1998 was low and we did not estimate survivorship. Populations in neighboring Saskatchewan and Alberta with similar or higher productivity showed significant annual decreases over the past decade (Hjertaas 1997, Wellicome 1997b). Our preliminary results suggested the owl population in Montana may have increased within the past 5 yr as prairie dogs rebounded from plague epizootics. However, future monitoring is warranted because productivity and density were both low, and because significant owl declines continue nearby in Canada.

Management of Burrowing Owls in southeastern Montana must consider population ecology and habitat selection of black-tailed prairie dogs. Managing plague is the greatest challenge to prairie dog conservation, and has similar potential to challenge management of Burrowing Owls in the Great Plains. Plague moved through prairie dog towns in southeastern Montana during the mid-1980s (C. Knowles unpubl. data), and reduced prairie dog populations to a level where plans to reintroduce black-footed ferrets were halted. Whether size or distribution of prairie dog towns influences epizootic severity or movement of plague remains unknown. However, because Burrowing Owls select the best, not the largest, remaining habitat patches (Butts and Lewis 1982, Warnock and James 1997), plague may severely reduce owl populations in Montana.

Burrowing Owls did not avoid nesting on prairie dog towns subjected to recreational shooting, and productivity of pairs nesting on or off shooting areas was similar. Although owls have been shot in other areas (Butts 1973), we found no evidence of shooting mortality in our area. Nonetheless, recreational shooting may have disrupted daytime foraging by adults and thus produced subtle negative effects. For example, owls fed extensively on diurnal prey (e.g., birds and grasshoppers) when the food demand of owl broods in southeastern Montana was highest, in mid- to late-July (see also Haug and Oliphant 1990). Food limits Burrowing Owl productivity during the nestling stage (Wellicome 1997a, 2000), so aboveground counts of juveniles in Montana would have underestimated nestling mortality if starvation had occurred belowground. In addition to maintaining nesting habitat, resource managers must ensure that grasslands and shrublands support the primary prey species taken by owls during the nesting season (e.g., mice and voles, meadowlarks, grasshoppers, and beetles).

Finally, management to benefit Burrowing Owls should consider historically-based negative attitudes toward prairie dogs because nesting owls were evenly distributed across both public and private lands. Many state agricultural agencies, including Montana's, continue to consider prairie dogs "vertebrate pests" requiring systematic "suppression" (Sections 7-22-2207 [6] and 80-7-1101 Montana Code Annotated). The acrimonious debate between agricultural and conservation interests impedes effective wildlife management. Conservation of prairie dog habitat can only proceed through partnerships between private citizens and government (Samson and Knopf 1994, Holroyd et al. 2001). To address both economic and conservation concerns, the Montana Prairie Dog Working Group is developing and implementing a statewide conservation plan for black-tailed prairie dogs. Incentives to maintain prairie dog habitat on private lands are an important component of the plan, as is the goal to maintain viable populations of associated species, such as the Burrowing Owl.

Acknowledgments

We thank the following ranchers for graciously granting access to private lands: A. Haughian, M. Haughian, P. Haughian, Q. Haughian, T. Haughian, and D. Reed C. Stuart and M. Ivie identified invertebrate prey remains, and J. Rozdilsky kindly loaned mammal specimens from the Burke Museum, University of Washington, Seattle. G. Holroyd, B. Olenick, J. Sidle, and T. Wellicome provided helpful comments on the manuscript. The U.S. Bureau of Land Management and Montana Fish, Wildlife, and Parks provided funding for this study in cooperation with Montana State University, Bozeman.

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NOCTURNAL FORAGING AND HABITAT USE BY MALE BURROWING OWLS IN A HEAVILY-CULTIVATED REGION OF SOUTHERN SASKATCHEWAN

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ABSTRACT.—Foraging habitat use of male Burrowing Owls (*Athene cunicularia*) was examined during the breeding season in a heavily-cultivated region of southern Saskatchewan. Four male Burrowing Owls were radio-tracked in June and July of 1997. The mean 95% Minimum Convex Polygon home range was 33.5 ha (range = 7.9–46.7 ha), and the 95% adaptive kernel home-range mean was 49.8 ha (range = 13.7–79.3 ha). Individual Chi-square analyses, of observed versus expected habitat use, revealed significant habitat selection in three of four owls. Crops and fallow were significantly avoided by two owls and one owl, respectively, and two owls significantly preferred pasture. Small-mammal abundance was highest in crops and right-of-way habitats and generally lowest in pastures, a pattern that was consistent among years, though small mammal abundance was higher overall in 1997 than in 1992 or 1993. Further study is needed to fully characterize nocturnal habitat requirements for Burrowing Owls, particularly if Canadian Species at Risk legislation calls for the protection of critical foraging habitat.

KEY WORDS: *Burrowing Owl*; Athene cunicularia; *nocturnal foraging*; habitat use; *home range*; *small mammals*; *telemetry*; *Saskatchewan.*

Forrajeo nocturno y uso de hábitat por un macho de Búho Cavador en una región altamente cultivada del sur de Saskatchewan

RESUMEN.—El uso del hábitat de forrajeo del macho de Búho Cavador (*Athene cunicularia*) fue examinado durante la estación reproductiva en una región altamente cultivada del sur de Saskatchewan. Cuatro búhos cavadores machos fueron rastreados con radio en junio y julio de 1997. La media 95% del rango de acción del polígono mínimo convexo fue 33.5 ha (rango = 7.9–46.7 ha), y el 95% de la media del rango de acción ajustable Kernel fue 49.8 ha (rango = 13.7–79.3 ha). El análisis individual Chi-cuadrado, del uso de hábitat observado versus el esperado, reveló una selección significativa de hábitat en tres de cuatro búhos. Los cultivos y el barbecho fueron evitados significativamente por dos y un búho, respectivamente, y 2 búhos prefirieron pasturas significativamente. La abundancia de pequeños mamíferos fue mas alta en los cultivos y hábitats de "derecho de paso" y generalmente mas bajo en pastos, un patrón que fue consistente entre años, aunque la abundancia de pequeños mamíferos fue mas alta en conjunto en 1997 que en 1992 o 1993. Son necesarios mayores estudios para caracterizar totalmente los requerimientos de hábitat nocturno para los Búhos Cavadores, particularmente si la legislación de las Especies Canadienses en Peligro clama por la protección del hábitat critico de forrajeo.

[Traducción de Victor Vanegas y César Márquez]

The Burrowing Owl (*Athene cunicularia*) is listed as an Endangered Species in Canada (Wellicome and Haug 1995) and is considered a Bird of Conservation Concern in the United States (Holroyd et al. 2001). Potential causes for the decline of this species in Canada include habitat loss and fragmentation (Wellicome and Haug 1995); pesticide use (James et al. 1990); mortality during migration, on wintering grounds (Haug et al. 1993), and during the breeding season (Clayton and Schmutz 1997); and reduced productivity (Hjertaas et al. 1995).

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Recent work in Saskatchewan (Wellicome et al. 1997, Wellicome 2000) indicates food limits productivity, leading to questions about foraging habitat use and associated prey abundance. Nest-site characteristics have been described for Burrowing Owls (MacCracken et al. 1985, Green and Anthony 1989); however, little is known about their home range and nocturnal habitat use (but see Haug and Oliphant 1990). A better understanding of nocturnal foraging habitat requirements will be imperative for Burrowing Owls if proposed Species at Risk legislation in Canada requires identification and conservation of "critical habitats."

Saskatchewan Environment and Resource Management initiated this study in order to address the above gaps in our knowledge. This study focuses on the use of nocturnal habitat by male owls during the brood-rearing stage. The study focuses on this period of nesting for the following reasons: 1) food supply at this stage is more limiting than during egg laying (Wellicome 1997, 2000); 2) nocturnal hunting is for small mammals, which comprise the majority of prey items (Schmutz et al. 1991, Plumpton and Lutz 1993, Wellicome 2000); and 3) the male owl is the main provider of food during this stage (Haug et al. 1993).

Study Area and Methods

The study area is in the Moist Mixed-Grasslands Ecoregion of southern Saskatchewan, south of the cities of Moose Jaw (50°22′N, 105°33′W) and Regina (50°27′N, 104°39′W) and west of the town of Weyburn (49°40′N, 103°52′W). Extensive agricultural lands, used mainly for the production of cereal crops, has left a heavily-fragmented environment. Widely-dispersed, small cattle or horse pastures constitute the remaining nesting sites for Burrowing Owls in the area. These nesting pastures are situated in a landscape dominated by seeded crop or fallow fields and hay fields. Riparian areas are infrequent and consist mainly of ephemeral streams or low-lying regions within croplands or pastures with some low-lying sites being used as hay fields.

Owl Trapping. The capture of male Burrowing Owls was initiated in late-May and early-June prior to hatching. Because of the paucity of available nesting pastures within the study area, most owls tended to nest in close proximity. Only one owl from any one pasture was used for this study, with a 3-km minimum separation between nests. We selected only breeding male owls for trapping and attempted to ensure equal distribution throughout the study area. Owls were trapped by placing noose carpets around the nest burrow entrance and nearby roost burrows (Bloom 1987). Noose carpets were baited with dead laboratory mice. To prevent accidental capture of the female, the nest burrow was temporarily plugged while the female was underground inside the burrow. Male owls usually returned to the nest burrow on their own; however, if the owl had not returned after 20–30 min, we would flush the owl from its roosting spot in the direction of the carpeted nest or roost burrows. Owls were generally caught within 1–2 hr, but some owls required several attempts before being caught.

Each captured owl was weighed and banded with a U S Geological Survey aluminum band and a unique combination of color bands. Necklace-style radio transmitters (<6.0 g; Merlin Systems Inc., Boise, Idaho) were placed on all captured owls. Because each owl weighed at least 140 g, the weight load of each transmitter was always ≤4%. All nests were monitored continuously throughout the season to ensure they were still occupied.

Telemetry. Owls were followed from sunset (2100 H) to sunrise (0500 H) between 20 June–21 July 1997. All owls were tracked for each of the 1-hr blocks at least once during the study. Owls were located using 3-element hand-held antennas and Model SRX 400 receivers (Lotek Engineering Inc., Newmarket, Ontario). Simultaneous bearings were taken on each owl at 10-min intervals for 1 hr by two researchers in constant radio contact. Telemetry stations were situated at road intersections, field borders, or other locations that could be easily located on aerial photos. In most cases, distance from observers to the owl was ≤750 m, with a maximum transmitter range estimated to be about 1.5 km. Three to four owls were followed each night, and no owl was monitored twice in one evening. Researchers searched the vicinity of a nest for the owl until it was located, ensuring complete coverage of the area used by the owl. Owls were not followed during high winds or rain.

Small Mammal Sampling. Relative abundance of small mammals was estimated in five discrete habitat types found within the study area in 1992, 1993, and 1997. The five habitats sampled were crop, fallow, pasture, hay, and right-of-way (ROW). Crop consisted mainly of barley or wheat fields and, less commonly, specialty crops such as field peas. Fallow fields were areas tilled on a regular basis (at least once prior to sampling) or had standing stubble present. Pastures were usually heavily grazed by cattle or horses and had either native or tame vegetation ROW were roadside ditches that were adjacent to any of the other habitat types, and were usually mowed once during the growing season. Hay fields were planted to a forb/grass mixture. Both ROW and hay were sampled prior to mowing or haying activities.

Transects of 10 Museum Special snap-traps, baited with peanut butter, were placed in each habitat type. Each transect was >25 m from any edges with traps spaced at 10-m intervals (Davis 1990). ROW habitat is restricted in width (10–15 m), so each trapline was placed in the center of the ROW and ran parallel to the road. Traps were pre-baited for 1 d and then set for three consecutive days

Trapping in all years took place within the same study area, but not in the same fields; however, all five habitats were trapped within each year. The sampling sites were distributed evenly throughout the study area each year, but traps were not set close to known Burrowing Owl foraging sites, avoiding any possible influences on owl foraging behavior.

Statistical Analysis. For the purposes of this study, 'home range' will refer to the area used by male owls from approximately the time that their chicks hatched to about the time that those chicks fledged. To reduce error, only those locations obtained from telemetry bearings of ≥40° and ≤140° were included. The cluster sampling strategy, adopted primarily for logistical reasons, can lead to autocorrelation of data points. To reduce the interdependence of data, we used locations separated by at least 20 min, which is ample time for the owls to traverse their home range.

Two methods were used to determine home-range size for the owls. The 95% minimum convex polygon (MCP) (White and Garrott 1990) method was used to facilitate comparison with Haug and Oliphant (1990). The 95% adaptive kernel method, an improved home-range estimator that takes into consideration the density of location estimates (Worton 1989), was also used. Home-range analyses were performed using the program Tracker (Version 1.1; Camponotus AB, Sweden) with default settings.

Error polygons were created for each location within program Tracker, following the method of Lenth (1981). Tracker uses a default bearing standard deviation of 8.0° to estimate error polygons. This value is lower than our bearing standard deviation assessed in the field (5.6°) but we accepted the higher value because of a low sample size (N = 12) in our error estimation. Utilized habitats were determined by overlaying this error ellipse on 1: 20 000 scale aerial photos of the study area. Proportional coverage of all habitats within the error ellipse was visually estimated, to the nearest 5%, accounting for 100% of the area.

Availability of habitats was determined by overlaying the home-range polygon for each owl on 1:20 000 scale aerial photos. A fine-scale dot-grid was then placed on top. To determine relative proportions of each habitat type, the number of dots were counted within each habitat type and then divided by the total number of dots for the entire home range. The expected distribution of telemetry locations was determined by multiplying the proportion of each available habitat by the total number of locations for each owl. Only locations >50 m from the nest were assumed to be foraging sites (Haug and Oliphant 1990), and this 50-m buffer was not included as available habitat. Six habitat types were defined using this method: pasture, crop, fallow, riparian, ROW, and farmyard. Pasture, crop, fallow, and ROW habitats follow the description given above for small mammal sampling. Riparian habitats consisted of small streams with associated vegetation running through pastures or crop/fallow fields. Farmyards represent all buildings, lawns and shelterbelts associated with the primary residence of the landowner.

The null hypothesis, that Burrowing Owls use habitats proportional to availability, was tested using a Chi-square analysis of observed versus expected habitat use locations (Neu et al. 1974, Zar 1996). To determine if a habitat was significantly preferred or avoided, simultaneous confidence intervals were calculated using the Bonferroni adjustment (Neu et al. 1974, Byers et al. 1984). Each owl was treated individually in the analysis because habitat-use distributions were heterogeneous (χ^2 = 12.92, df = 5, P = 0.03, therefore reject H_O: that habitat use was homogenous; Zar 1996:467).

Relative abundance of small mammals is presented as the number of captures per 100 trap nights corrected for closed traps (Nelson and Clark 1973). All species caught were pooled into the 'small mammal' category. Trapping effort in 1997 was approximately half of that in 1992–1993 (46 total transects vs. 110 and 95, respectively), but we feel this is sufficient for the level of comparison presented in this paper.

Table 1. Breeding season home-range size of four male Burrowing Owls (BUOW) near Regina, Saskatchewan, in 1997. MCP = Minimum Convex Polygon.

	95% MCP (ha)	95% ADAPTIVE KERNEL (ha)	N
BUOW No. 1	43.3	56.1	54
BUOW No. 2	7.9	13.7	66
BUOW No. 3	46.7	79.3	58
BUOW No. 4	36.2	50.3	56
Mean (SE)	33.5 (8.8)	49.8 (13.6)	58.5

RESULTS

Transmitters were attached to 11 male owls, but one owl was depredated 8–10 d later by an avian predator. The transmitters on six other owls failed, primarily because owls damaged or removed antennae. These failures occurred 7–10 d after transmitter attachment. Data collected on these owls were insufficient for inclusion in this study due to limited data points (<15) and inadequate temporal coverage. Consequently, adequate data were available for only four owls. Mean MCP home-range size for the four owls is 33.5 ha (SE = 8.8), and mean kernel home range is 49.8 ha (SE = 13.6; Table 1).

Habitat-use analysis shows that three of the owls used habitats in a significantly different manner than expected under the hypothesis of proportional use (Table 2). Owl No. 1 was the exception, showing no significant departure from expected habitat use. Two of the remaining owls avoided crop at varying levels of significance, and only Owl No. 3 significantly avoided fallow (Table 2). Two owls also showed a significant preference for pasture (Table 2).

In 1132 trap nights in 1997, four species of small mammals were caught. Deer mice (*Peromyscus maniculatus*) were most common, occurring in all sampled habitats. Meadow voles (*Microtus pennsylvanicus*) were second highest in abundance, but were only found in hay fields, ROW, and pastures. A few house mice (*Mus musculus*) and an unknown species of shrew (*Sorex* spp.) were caught, but only in ROW habitat. Compared with data from 1992–93, small mammals as a group in 1997 had a higher abundance in all habitat types, except pastures (Fig. 1).

DISCUSSION

It is difficult to extrapolate habitat associations from four Burrowing Owls to the entire owl population. Patterns seen in this study may be indicative of Burrowing Owl behavior on a larger scale, but broad-scale conclusions or inferences from this study must be kept in check. This is especially important when one considers the uniqueness of 1997 in terms of prey abundance (Fig. 1). There are no long-term small mammal studies for this area, but anecdotal evidence does exist to support that 1997 was a unique year. Local landowners indicated they had not seen such abundance of small mammals since the late-1960s. Additionally, sightings of several species of raptor increased substantially from previous years, most notably the Short-eared Owl (*Asio flammeus*; Poulin et al. 2001). This species is well known to be irruptive and is thought to track small mammal populations, in particular *Microtus* species (Holt and Leasure 1993). Meadow voles were a great deal higher during the breeding season in 1997 than in previous years (Wellicome 2000, Poulin et al. 2001).

Abundant prey in 1997 may explain the relatively small home ranges of the four owls in this study. Haug (1985) recorded a mean home range of 241 ha (range = 14–481 ha) for six male owls near Saskatoon in 1982–83. The estimated 2-yr mean for small mammal abundance in the Saskatoon study area (data not recorded by habitat type) was 3.4 mice/100 trap nights (Haug 1985). This is substantially lower than the abundance of 22.7 mice/100 trap nights recorded in this study area in 1997 (all habitats combined).

In general, Burrowing Owls in this study avoided croplands and fallow, preferred pastures, and utilized other habitats in proportion to occurrence on the landscape. Avoidance of crops can be explained by the structure of the environment: crops tend to be tall (>0.5 m) and dense, limiting access to prey. Haug (1985) recorded similar results (although with a higher level of significance): owls avoided croplands and grazed pastures and preferred habitats with a grass/forb cover, including ROW, hay fields, and ungrazed pastures. The avoidance of cropland and higher use of pastures in this study indicates that prey abundance alone does not drive foraging-habitat selection in these owls, especially in a high-food year.

While this study experienced technical difficulties with respect to the transmitters, we hope this does not dissuade continued research on Burrow-

Table 2. Observed and expected habitat use and Bonferroni confidence intervals (CI) of four Burrowing Owls (BUOW) near Regina, Saskatchewan, in 1997. Asterisks show level of significance for the CI: * = 0.1, ** = 0.05, and *** = 0.01. Results from habitat-use analysis for BUOW No. 1: $\chi^2 = 7.03$, df = 5, $P = 0.22$; BUOW No 2: $\chi^2 = 11.66$, df = 3, $P < 0.01$; BUOW No. 3: $\chi^2 = 25.95$, df = 2, $P < 0.01$; BUOW No. 4: $\chi^2 = 11.81$, df = 5, $P = 0.04$. "n/a" indicates that habitat was not present in the individual's home range.

Habitat Type	Observed Proportion	Expected Proportion	Bonferroni Confidence Intervals
BUOW No. 1			
Crop	0.12	0.28	0.12 ≤ x ≤ 0.45
Fallow	0.52	0.40	0.23 ≤ x ≤ 0.58
Pasture	0.17	0.13	0.01 ≤ x ≤ 0.25
Riparian	0.08	0.07	0.00[a] ≤ x ≤ 0.10
ROW	0.01	0.04	0.00[a] ≤ x ≤ 0.16
Farmyard	0.04	0.09	0.00[a] ≤ x ≤ 0.19
BUOW No. 2			
Crop	0.21	0.37	0.21 ≤ x ≤ 0.52**
Fallow	0.42	0.33	0.17 ≤ x ≤ 0.48
Pasture	0.27	0.17	0.05 ≤ x ≤ 0.29
Riparian	n/a	n/a	—
ROW	0.10	0.14	0.03 ≤ x ≤ 0.26
Farmyard	n/a	n/a	—
BUOW No. 3			
Crop	0.13	0.28	0.14 ≤ x ≤ 0.43*
Fallow	0.19	0.35	0.20 ≤ x ≤ 0.50*
Pasture	0.68	0.36	0.16 ≤ x ≤ 0.56***
Riparian	n/a	n/a	—
ROW	n/a	n/a	—
Farmyard	n/a	n/a	—
BUOW No. 4			
Crop	0.14	0.25	0.10 ≤ x ≤ 0.41
Fallow	0.41	0.43	0.26 ≤ x ≤ 0.61
Pasture	0.33	0.19	0.05 ≤ x ≤ 0.33**
Riparian	0.08	0.05	0.00[a] ≤ x ≤ 0.13
ROW	0.01	0.02	0.00[a] ≤ x ≤ 0.08
Farmyard	0.02	0.05	0.00[a] ≤ x ≤ 0.13

[a] The true lower confidence limit was a negative number and was therefore adjusted to 0.00.

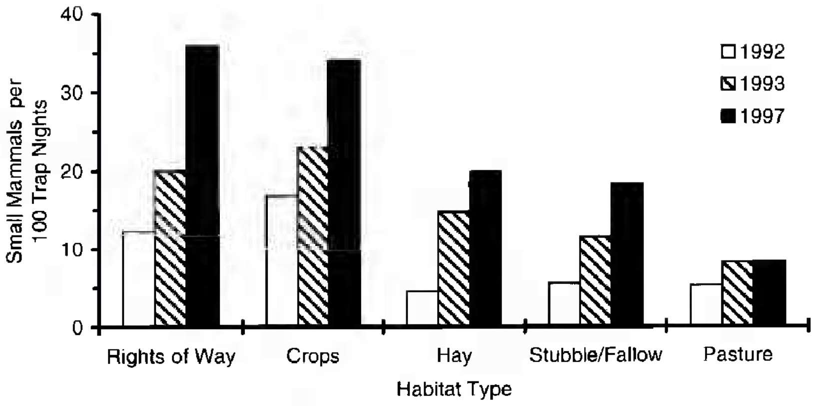

Figure 1. Small mammal abundances in the Burrowing Owl study area in 1992, 1993, and 1997. Trapping was conducted in June and July of each year. Four species were captured (listed in order of abundance): deer mouse, meadow vole, house mouse, and an unidentified shrew species.

ing Owl foraging ecology. The necklace-style design of the transmitters may have contributed to their destruction by the owls. Necklace transmitters are required to be loose-fitting to allow for food intake and pellet regurgitation. This loose fit leads to constant movement of the transmitter, possibly provoking the owls to attempt to remove them. Backpack-style transmitters may be an alternative as they are snug-fitting, but are more difficult to attach, requiring additional time to handle the birds. Continued exploration of transmitter design and attachment techniques is needed, including experiments on captive-raised Burrowing Owls if possible.

ACKNOWLEDGMENTS

We would like to thank all the landowners associated with this study for their interest in conserving Burrowing Owls on their land and for allowing researchers unlimited access to their property. Saskatchewan Environment and Resource Management provided logistic and financial support for the project. Theresa Hegg provided excellent assistance in the field, especially during the night telemetry. R.G. Poulin and L.D. Todd helped trap owls and provided much-needed moral support. J. Gervais and L.D. Todd provided critical comments on earlier drafts that greatly improved the final manuscript. Thanks also to D. McKinnon for his comments and valuable insights on study design and the pros and cons of telemetry studies.

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J Raptor Res. 35(4):310–315

BURROWING OWL POPULATION-TREND SURVEYS IN SOUTHERN ALBERTA: 1991–2000

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Abstract.—In Alberta, standardized diurnal call-playback surveys for Western Burrowing Owls (*Athene cunicularia hypugaea*) were conducted between 1991–2000 near the town of Hanna, and between 1993–2000 near the town of Brooks. In most years, the Brooks and Hanna surveys encompassed 10 360 ha and 7060 ha, respectively. Both survey areas are located within the historical breeding distribution of Burrowing Owls in predominantly native mixed-grass prairie habitat. The Hanna surveys indicated that the density of nests ($\bar{x}$ = 13.7 nests per 100 km^2, range = 2.8–32.6) declined significantly between 1991 and 2000. The decline in the Hanna area was most pronounced between 1991 (32.6 nests/100 km^2) and 1997 (2.8 nests/100 km^2) and recent surveys have found few nests. The Brooks surveys indicate that the density of nests ($\bar{x}$ = 8.9 nests/100 km^2, range = 1.9–13.5), although lower than Hanna, did not decrease during the course of the surveys. The significant decline in Hanna is most likely indicative of the contraction of the northern edge of the breeding distribution of Burrowing Owls in Alberta and suggests that the population will soon become extirpated from that area.

Key Words: *Burrowing Owl;* Athene cunicularia; *monitoring; population trend; survey; call-playback; Alberta; Canada.*

Estudios de la tendencia de la población del Búho Cavador en el sur de Alberta: 1991–2000

Resumen.—En Alberta, fueron llevados a cabo estudios diurnos estandarizados por medio de llamados con sonidos pregrabados para los Búhos Cavadores Occidentales (*Athene cunicularia hypugaea*) entre 1991–2000 cerca de la ciudad de Hanna, y entre 1993–2000 cerca de la ciudad de Brooks. En la mayoría de años, los estudios de Brooks y Hanna abarcaron 10 360 ha y 7060 ha, respectivamente. Ambas áreas

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de estudio están localizadas dentro de la distribución de apareamiento histórica de los Búhos Cavadores en el hábitat predominantemente nativo de praderas de pastos mixtos. Los estudios de Hanna indican que la densidad de nidos ($\bar{x}$ = 13.7 nidos por 100 km^2, rango = 2.8–32.6) declinó significativamente entre 1991 y el 2000. El declive en el área de Hanna fue mas pronunciado entre 1991 (32.6 nidos/100 km^2) y 1997 (2.8 nidos/100 km^2) y los estudios recientes han encontrado pocos nidos. Los estudios en Brooks indican que la densidad de nidos ($\bar{x}$ = 8.9 nidos/100 km^2, rango = 1.9–13.5), aunque mas baja que la de Hanna, no decreció durante el curso de los estudios. El declive significativo en Hanna probablemente es mas indicativo de la contracción del borde norte de la distribución de los apareamientos de los Búhos Cavadores en Alberta y sugiere que la población pronto comenzará a ser extirpada de esa área.

[Traducción de Victor Vanegas y César Márquez]

Western Burrowing Owls (*Athene cunicularia hypugaea*) show a strong association with Great Plains habitat on the Canadian breeding grounds, and in Alberta they nest in the Mixed-grass Ecoregion in the southeastern corner of the province. Across North America, native mixed-grass prairie has been converted to agricultural cropland or non-native planted pasture, and less than 33% currently remains intact (World Wildlife Fund 1989). Conversion to cropland has been particularly severe in Canada, as only 24% of the original prairie habitat remains (Trottier 1992). In Alberta, the Mixed-grass Ecoregion comprises almost 12% of the province, of which more than half has been significantly altered by agriculture in the last century (Strong and Leggat 1992).

Evidence from private landowners, censuses, and individual research projects indicate that Burrowing Owl populations have declined in every historically-occupied province in Canada (Wedgwood 1978, Haug and Didiuk 1991, Wellicome and Haug 1995, Hjertaas 1997, James et al. 1997, Wellicome 1997). Monitoring in Manitoba has shown a decline from 34 to 1 nest between 1987–96 (De Smet 1997). From 1997–2000 the number of nests found in Manitoba fluctuated between 1–3 nests, so Burrowing Owls are on the verge of extirpation in that province (K. De Smet pers. comm.). Continued captive breeding and reintroduction efforts seem to have maintained the extremely small population that remains in British Columbia, near Kamloops, but the wild provincial population was probably extirpated since the early-1980s (Leupin and Low 2001). Because of these declines, Burrowing Owls have been listed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) as threatened since 1978 (Wedgwood 1978) and as endangered since 1995 (Wellicome and Haug 1995). The following is a summary of results based from six standardized surveys in the Hanna area between 1991–2000 and seven surveys in the Brooks area between 1993–2000.

Methods

Diurnal call-playback surveys were first initiated in 1991 to determine Burrowing Owl density and abundance in Alberta. Survey blocks were established in habitat containing more than 75% native prairie near Hanna in 1991, and 135 km south near Brooks in 1993. Both survey areas are within the historical breeding range of Burrowing Owls in Alberta. Continued monitoring of these standardized survey blocks allows for an examination of trends of two populations over most of the last decade. Prior to implementation of these surveys, no standardized survey protocol existed for Burrowing Owls. We collected survey data from the Hanna area during 6 yr (between 1991–2000) and during 7 yr from the Brooks area (between 1993–2000).

The survey protocol is designed to locate active nests within a sample of quarter-sections. Searches are conducted one quarter-section (64.7 ha each) at a time by two stationary observers, using all-terrain vehicles to move between quarter-sections. The quarter-section was chosen as the unit of size for surveys because fences, roads, and edges of agricultural fields delineated some of the quarter-section boundaries. Pairs of observers used binoculars, spotting scopes, and broadcasts of a territorial male breeding call while conducting surveys in June–July Surveys conducted at this time of year record nests prior to fledging, yet ensure that detection of owls is not greatly reduced by seasonal vegetation growth. Playback of the territorial male breeding call has been shown to be effective at increasing the detection of owls (Haug and Didiuk 1993). The pair of observers stood ca. 200–500 m apart, choosing the best vantage points (usually hilltops) so that the greatest area of the quarter-section was visible. Observers sometimes stood on their all-terrain vehicle to increase their field of view. Different observers surveyed the same quarters in consecutive years to reduce bias that might result from observer memory. Recorded breeding calls were broadcast from a position in the upwind third of the quarter-section, thus ensuring the call reached the entire quarter-section. The quarter-sections were surveyed in a downwind-to-upwind sequence to reduce the potential for downwind owls to habituate to the breeding call-playback. Generally, observation points were at the same locations across years because we used the higher hilltops for sampling in quarter-sections. However, pre-

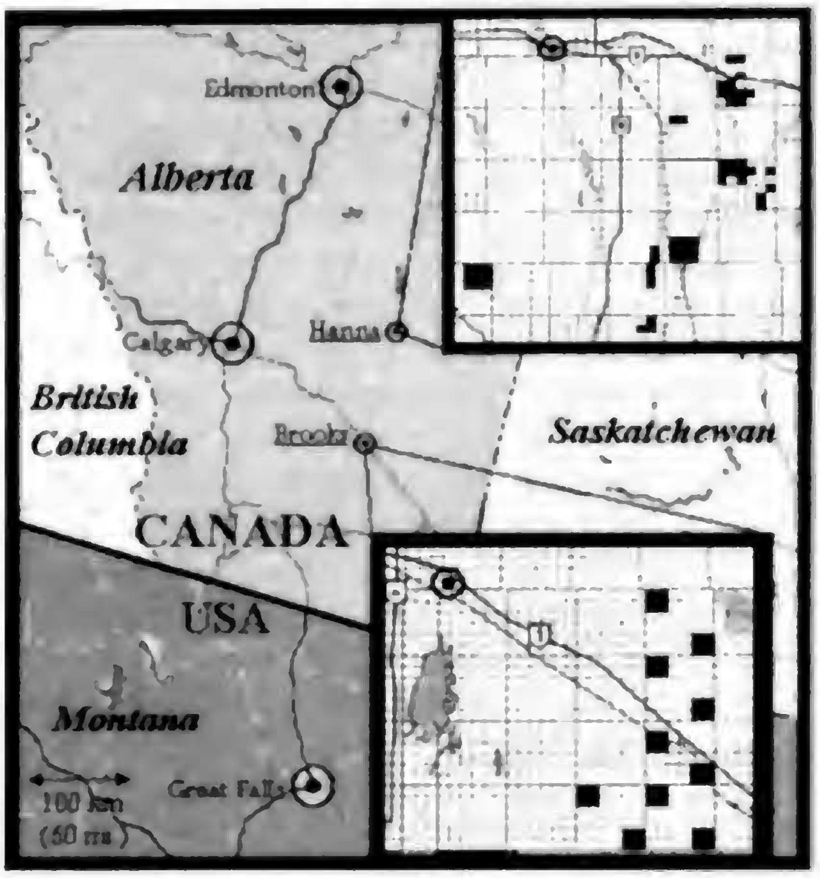

Figure 1. Locations of Hanna and Brooks survey areas in Alberta. Black squares in insets show areas surveyed for Burrowing Owls, and squares in grid are each 1.6 km by 1.6 km (one section of land).

vailing wind direction affected the selection of observation points and resulted in some variation in sampling points across years. When observers encountered a cultivated quarter-section, they scanned for owls from the perimeter while driving approximately 40 km/hr. Although driving the perimeter of cultivated land may increase search effort by increasing time spent surveying, nests were never located in any cultivated land over the course of the surveys. Because 9–10% of the quarter-sections surveyed were partially or entirely under cultivation, seeded pasture, or nonnative hay, the habitat surveyed reflects the fragmented habitat present in Alberta, albeit at a lower level of fragmentation than the provincial average for the Mixed-grass Ecoregion.

Quarter-sections were surveyed in three consecutive 5-min observation intervals during which we emphasized sighting owls. During the first 5-min interval, 360° silent scanning allowed for initial observations of owls, potential nests, and roosts. This first passive interval may also have allowed any disturbance from the all-terrain vehicle to subside and thus increase the response of the owl to the breeding call-playback. The observer in the upwind position then broadcast a male breeding call for the next 5 min while continuing the 360° scan. The observers would complete the survey after a final 5-min silent observation interval and 360° scan. Since all owls were observed in the first 10 min, the final 5-min interval was dropped from the 2000 Hanna survey and the 1999 and 2000 Brooks surveys.

The quarter-sections in Hanna (Fig. 1) were first selected based on observations in a previous study (J. Schmutz unpubl. data) that evaluated the effectiveness of call-playback survey methodology. Thus, sites were not randomly selected and survey blocks were not evenly distributed across the landscape. Thirty-two of 109 quarter-sections were chosen for the survey because they had supported owls in 1990 and earlier. Except in 1994 (81 quarter-sections) and 2000 (76 quarter-sections), all 109 quarter-sections were surveyed each year in Hanna (Table 1). The fewer number of quarter-sections surveyed in 2000 was the result of a single private landowner who denied observers access to his land.

Quarter-sections were uniformly distributed in Brooks in 10 survey blocks, each containing 16 quarter-sections (Fig. 1). These blocks were systematically located in the northwest and southeast corners of five adjacent townships without prior knowledge of owl presence or absence. Except in 1993 (128 quarter-sections), all 160 quarter-sections were surveyed each year in Brooks (Ta-

Table 1. Number of Burrowing Owl nests observed, nest density, percent change in nest density from previous year of survey, and number of quarter-sections surveyed in the Hanna and Brooks areas.

	SURVEY AREA							
	HANNA				BROOKS			
YEAR	NO. OF NESTS	PER 100 km²	PERCENT CHANGE	NO. OF 1/4's	NO. OF NESTS	PER 100 km²	PERCENT CHANGE	NO. OF 1/4's
1991	23	32.6	—	109	—	—	—	—
1992	—	—	—	—	—	—	—	—
1993	14	19.8	−39	109	6	7.2	—	128
1994	9	17.2	−13	81	2	1.9	−73	160
1995	—	—	—	—	12	11.6	500	160
1996	—	—	—	—	—	—	—	—
1997	2	2.8	−83	109	14	13.5	17	160
1998	4	5.7	100	109	10	9.7	−29	160
1999	—	—	—	—	10	9.7	0	160
2000	2	4.1	−28	76	9	8.7	−10	160

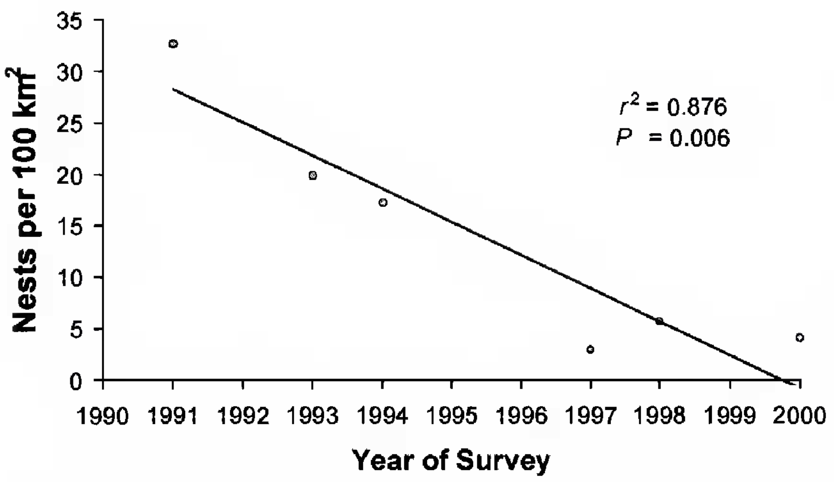

Figure 2. Nest densities and linear regression ($F = 28.1$, $r^2 = 0.88$, $P < 0.01$) line for Hanna survey area 1991–2000.

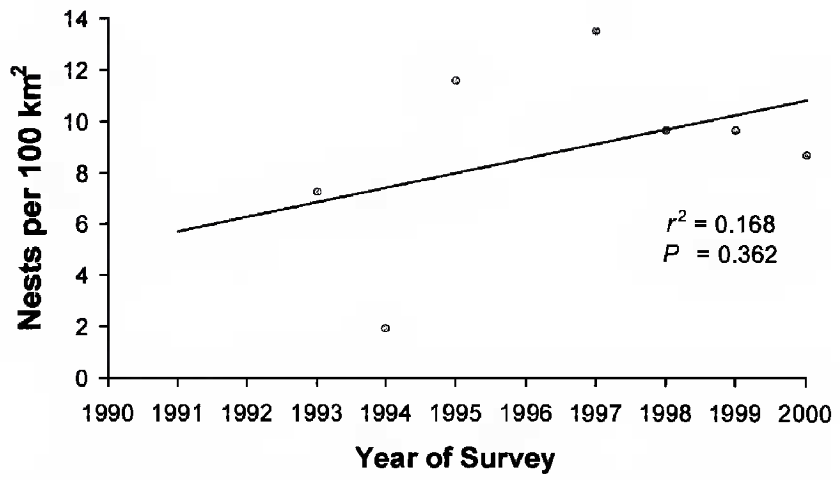

Figure 3. Nest densities and linear regression ($F = 1\ 0$, $r^2 = 0.17$, $P = 0.36$) line for Brooks survey area 1993–2000.

ble 1). Half of the area that was not surveyed in 1993 was substandard mixed-grass prairie and had been broken and seeded. No nests were observed in those quarter-sections during any other year of the survey. Thus, the effect of excluding this area in 1993 on the results of the Brooks survey was likely negligible.

Every owl observation was investigated for evidence of nesting before proceeding to the next quarter-section in the survey. Evidence for nesting included: 1) the presence of juvenile owls; 2) a pair of owls (pair bonds usually do not endure unless a brood is raised); or 3) one owl and abundant nesting material (manure or dung), whitewash, pellets, and prey remains present, as well as loosened soil on the burrow mound.

Certain weather conditions affect owl behavior (e.g., crouching low in a burrow) and reduce the probability of owl detection. Therefore, surveys were not conducted when: 1) temperatures were >30°C (surveys were started shortly after sunrise and generally did not continue into mid-afternoon); 2) wind speeds were >20 km/hr; or 3) it was raining. Nests found outside of the prescribed survey area were not included in this analysis.

RESULTS

Reduction of the area covered by the surveys in 1993, 1994, and 2000, large variation in the number of nests per quarter-section (because of the semicolonial nature of nesting owls), and the high percentage (80–98%) of quarter-sections surveyed that contained no nests, confound population trend analysis at the quarter-section scale. Population analysis was therefore conducted using linear regression of annual nest densities for the whole of each survey area.

Between 1991 and 2000, the number of nests observed in the Hanna survey decreased substantially, while the number of nests observed in the Brooks survey between 1993 and 2000 increased (Table 1). The mean number of nests found during the surveys was nine for both survey areas. The annual nest density in the Hanna surveys showed a significant ($P < 0.05$) negative trend closely fitting the regression line ($F = 28.1$, $P < 0.01$, $r^2 = 0.88$; Fig. 2), but there was no significant relationship in nest density over time in the Brooks area ($F = 1.0$, $P = 0.36$, $r^2 = 0.17$; Fig. 3). The mean nest density in Hanna was higher but more variable (13.7 nests/100 km^2, SE = 4.77, $N = 6$) than in Brooks (8.9 nests/100 km^2, SE = 1.39, $N = 7$) due to the high densities in the early years of the Hanna survey.

DISCUSSION

It could be argued that results should be calculated using only quarter-sections surveyed consistently across all years. Eliminating quarter-sections not surveyed across all years of the survey reduces the number of quarter-sections in Hanna by more than 50% (109 to 53), and by 20% (160 to 128) in Brooks. Eliminating these quarter-sections reduces the number of nests located in the surveys by 1–3 nests/yr, but unreasonably inflates the estimated nest densities by 53% in Hanna and 18% in Brooks. This effect is especially evident in higher density years (e.g., nest density in Hanna in 1991 is nearly doubled from 32.6 to 61.2 nests/100 km^2). However, either including or excluding those quarter-sections not surveyed in all years made little difference to the slopes of linear regression lines for Hanna or for Brooks.

The initial decline in the number of nests located during early surveys in Hanna (1991–93) may be biased, as 29% of these quarter-sections were established with prior knowledge of owl presence. Starting the surveys on occupied quarter-sections could initially inflate the estimated decline (Rich 1984); however, most quarter-sections adjacent to formerly occupied quarters were also included in the Hanna survey, decreasing the likelihood that owls that dispersed even moderate distances between years would be subsequently missed. It is unlikely that the continued decline in later survey years and the dramatic difference in annual nesting densities resulted from non-random quarter-section selection. The negative slope of the Hanna regression lines concur with trends shown over larger areas by other population estimates in Alberta (Wellicome 1997), Saskatchewan (Hjertaas 1997), and Manitoba (De Smet 1997). Unless this trend is reversed, the Burrowing Owl population near Hanna will likely become extirpated.

Although annual nest densities in Brooks were much lower than those in Hanna between 1991–94, nest densities have not declined overall in Brooks. The approximately stable population trend in Brooks is the only non-negative population trend that has ever been documented in Canada. Future surveys may ascertain if the Brooks population remains relatively stable at a lower density than in the Hanna area or if the Brooks population will decline as the northern edge of Burrowing Owl range continues to contract southward. Ongoing research in areas adjacent to the Brooks survey quarter-sections indicates that immigration and emigration play a large factor in maintaining this population, as few banded owls have returned to the study site (D. Shyry unpubl. data). If few owls return after migration, breeding and natal dispersal must be long-distance, or else mortality on the migration routes and overwintering sites must be high.

Nest densities determined by the 2000 Brooks surveys were very similar to nest densities determined independently by random point-count surveys conducted across southeastern Alberta. Although the random point counts surveyed five times more area than the Brooks survey, the resulting nest densities (8.63 nests/100 km^2 in 2000) closely resemble densities determined by the Brooks surveys (D. Scobie unpubl. data). This concurrence indicates that the Brooks surveys are likely a representative subsample of densities south of the contracting northern limit of the Burrowing Owl breeding range.

Burrowing Owl population trends from Hanna and Brooks were derived from surveys of large areas with a standardized protocol that has not been applied in any other jurisdiction. Given that the area of mixed-grass prairie has not decreased notably in either of the two survey areas over the past decade, yet population trends differ considerably, it is unclear if differing land-management practices (see Clayton and Schmutz 1999), other environmental factors (e.g., precipitation, prey abundance, predator abundance), owl behaviors (i.e., dispersal, immigration, emigration), and/or large-scale (i.e., continental) population declines are influencing the separate trends. In light of its proximity to the northern limit of the Burrowing Owl breeding range, Hanna's significantly declining nest densities may result from the contraction of the breeding range (Wellicome 1997), which could be a symptom of a shrinking continental population.

ACKNOWLEDGEMENTS

Surveys were made possible by the keen observations of G. Court, L. Dube, K. Grisley, L. Gudmundson, H Hargrove, J. Hauser, E. Hoffman, J. Kasdorf, R. Lee, C Marshall, S. Milan, D. Moody, J. Nicholson, C. Scobie, R. Sissons, J. Smith, J. Taygert, B. Treichel, H. Vriend, D. Wood, and the authors. Thanks to J. Belthoff and C. Conway who provided constructive reviews of early drafts of this manuscript. G. Court and S. Brechtel (Alberta Environment) provided generous financial support for these surveys and summary reports. Gracious thanks to the Eastern Irrigation District (Brooks) and the private landowners near Hanna who have offered ongoing support of these surveys.

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J Raptor Res. 35(4):316–321

OCCURRENCE OF BURROWING OWLS IN BLACK-TAILED PRAIRIE DOG COLONIES ON GREAT PLAINS NATIONAL GRASSLANDS

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Abstract.—The United States Department of Agriculture (USDA) Forest Service classifies the Burrowing Owl (*Athene cunicularia*) as a sensitive species on Great Plains National Grasslands, although no grassland-wide assessment had been conducted prior to the survey described here. During spring and summer 1998, most black-tailed prairie dog (*Cynomys ludovicianus*) colonies on National Grasslands were examined for the presence of Burrowing Owls. Of 582 colonies examined for Burrowing Owls, 444 (76%) showed signs of black-tailed prairie dog activity. Remaining colonies examined (N = 138) were inactive due to sylvatic plague (*Yersinia pestis*), shooting, or poisoning. We observed Burrowing Owls at 322 (55%) of the 582 colonies: owls were detected on 307 (69%) of 444 active colonies and 15 (11%) of 138 inactive colonies. Among National Grassland units, the percentage of colonies occupied by owls ranged from 16–93%. Burrowing Owl occupancy of active black-tailed prairie dog colonies was higher in the southern Great Plains (93%) than in the northern Great Plains (59%). National Grasslands occur primarily in the western Great Plains from North Dakota to Texas and encompass approximately 1.5 million ha of short- and mixed-grass prairie, most of which is potential habitat for black-tailed prairie dogs. Of this potential habitat, prairie dog colonies currently occupy 17 075 ha. Thus, there is substantial

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National Grassland area for prairie dog colonies to increase and provide additional nesting opportunities for Burrowing Owls.

Key Words: *Burrowing Owl*; Athene cunicularia; *black-tailed prairie dog*; Cynomys ludovicianus; *breeding distribution*; *survey*; *National Grasslands*; *Great Plains*.

Ocurrencia de los Búhos Cavadores en colonias de perros de la pradera en los Pastizales Nacionales de las Grandes Llanuras

Resumen.—El Servicio de Bosques del Departamento de Agricultura de los Estados Unidos (USDA) clasificó al Búho Cavador (*Athene cunicularia*) como una especie sensitiva en los Pastizales Nacionales de las Grandes Llanuras, aunque una extensa evaluación en zonas sin pastizales ha sido conducida antes del estudio descrito aquí. Durante la primavera y verano de 1998, la mayoría de colonias de perros de la pradera de cola negra (*Cynomys ludovicianus*)en los Pastizales Nacionales fueron examinada buscando Búhos Cavadores. De 582 colonias examinadas, 444 (76%) mostraron señales de actividad de los perros de la pradera. Las colonias examinadas restantes (N = 138) estaban inactivas debido a la plaga de (*Yersinia pestis*), caza, o envenenamiento. Observamos Búhos Cavadores en 322 (55%) de las 582 colonias: los búhos fueron detectados en 307 (69%) de las 444 colonias activas y 15 (11%) de las 138 colonias inactivas. Entre las unidades de los Pastizales Nacionales, el porcentaje de colonias ocupadas por los búhos estuvo en el rango de 16–93%. La ocupación del Búho Cavador de colonias activas de perros de la pradera de cola negra fue mas alta en las Grandes Llanuras del sur (93%) que en las Grandes Llanuras norteñas (59%). Los Pastizales Nacionales ocurren ante todo en las Grandes Llanuras occidentales desde Dakota del Norte a Texas y comprenden aproximadamente 1.5 millones de ha de praderas de hierbas cortas y mixtas, la mayoría de las cuales son hábitats potenciales para los perros de la pradera de cola negra. De estos hábitats potenciales, las colonias de perros de la pradera actualmente ocupan 17 075 ha. De tal manera, que allí hay un área substancial de Pastizales Nacionales para colonias de perros de la pradera que pueden incrementar y proveer de oportunidades adicionales de anidación para los Búhos Cavadores.

[Traducción de Victor Vanegas y César Márquez]

The Great Plains constitutes at least one-third of the breeding range of the Burrowing Owl (*Athene cunicularia*) in North America (Haug et al. 1993, Sheffield 1997). Within this region, burrows of black-tailed prairie dogs (*Cynomys ludovicianus*) provide nest sites for Burrowing Owls (Butts and Lewis 1982, Desmond 1991). Historically, the main source of nest burrows in the Great Plains must also have been the estimated 40–100 million ha of black-tailed prairie dog colonies (hereafter, 'colonies') that occurred in short- and mid-grass prairies (Anderson et al. 1986, Mulhern and Knowles 1996).

Indeed, enormous colonies were not uncommon. Merriam (1902) stated that one colony in Texas covered approximately 65 000 km^2. However, such large colonies no longer exist. Conversion of grassland to cropland, intensive poisoning programs (Fagerstone and Ramey 1996), and sylvatic plague (*Yersinia pestis*; Cully 1993) have decimated the black-tailed prairie dog. Colony fragmentation is significant (Flath and Clark 1986); most remaining colonies are ≤40 ha in size and are isolated from other colonies (USDA Forest Service unpubl. data). The black-tailed prairie dog, a keystone species (Kotliar et al. 1999, Kotliar 2000), is now a candidate for listing as a threatened species under the Endangered Species Act (ESA, United States Fish and Wildlife Service 2000).

Given the decline of the Burrowing Owl in Canada (Wellicome and Haug 1995, James and Espie 1997, Wellicome 1997), the Nebraska panhandle (Desmond et al. 2000), North Dakota (Murphy et al. 2001), and elsewhere in the Great Plains (James and Espie 1997), we decided to assess the occurrence of Burrowing Owls on Great Plains National Grasslands. The USDA Forest Service administers approximately 1.5 million ha of National Grasslands from North Dakota to Texas, and the Forest Service has classified the Burrowing Owl as a sensitive species. Accordingly, the species warrants monitoring and management to prevent it from decreasing toward threatened or endangered status under the ESA. Here, we quantify the presence and distribution of Burrowing Owls in most of these colonies. Although Burrowing Owls nest in

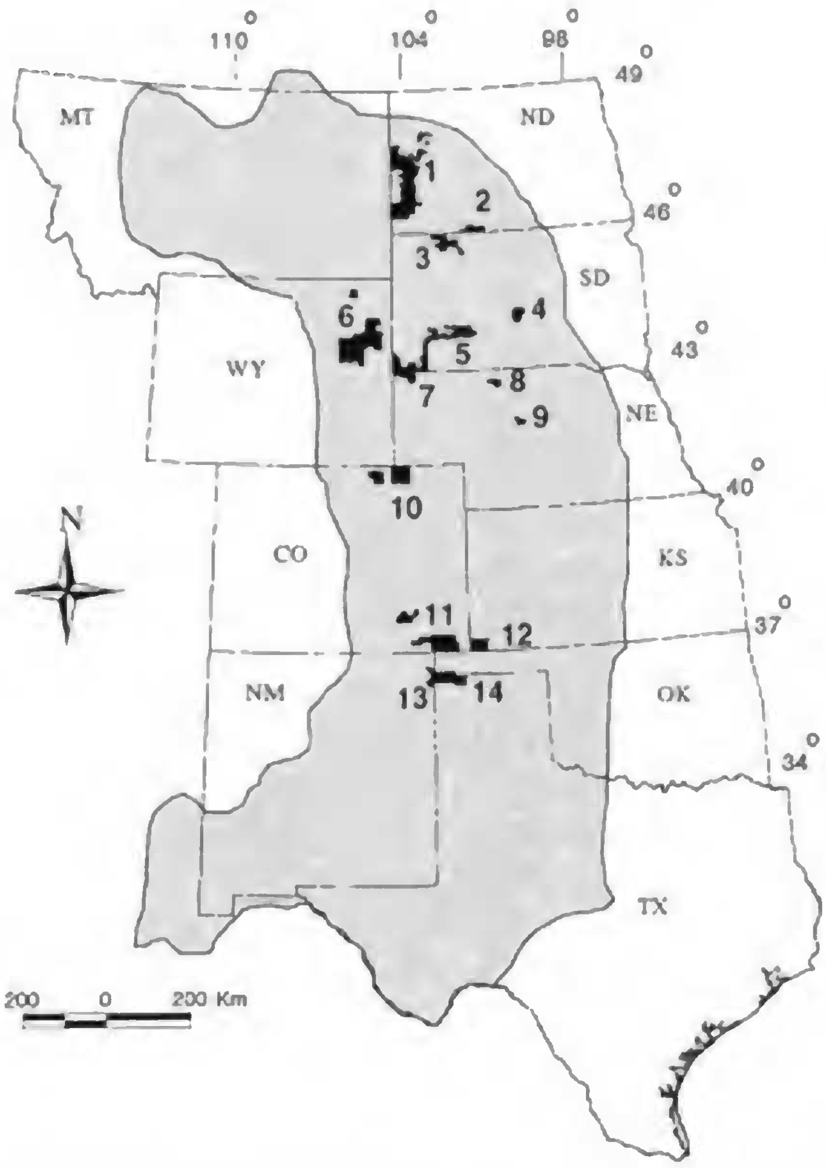

Figure 1. Location of Great Plains National Grasslands and Forests: 1 = Little Missouri, North Dakota; 2 = Cedar River, North Dakota; 3 = Grand River, South Dakota; 4 = Fort Pierre, South Dakota; 5 = Buffalo Gap, South Dakota; 6 = Thunder Basin, Wyoming; 7 = Oglala, Nebraska; 8 = McKelvie National Forest, Nebraska; 9 = Nebraska National Forest, Nebraska; 10 = Pawnee, Colorado; 11 = Comanche, Kansas; 12 = Cimarron, Colorado; 13 = Kiowa, New Mexico; 14 = Rita Blanca, Oklahoma and Texas. The stippled area is the range of the black-tailed prairie dog.

badger (*Taxidea taxus*) and other mammalian burrows, the principal burrow habitat on National Grasslands is provided by black-tailed prairie dogs.

STUDY AREA AND METHODS

We located and mapped all colonies on National Grasslands (Fig. 1). National Grasslands that were surveyed are located in the Great Plains-Palouse Dry Steppe Province (Bailey 1995) and include short- and mixed-grass prairie with some valley and badlands topography. Most National Grasslands contain extensive areas of restored grasslands, which were in cropland through the 1930s.

Locations of most colonies on northern Great Plains National Grasslands were documented before this project began. During 1997–98, we calculated the area of all colonies largely through the use of differentially corrected positional data acquired from the Global Positioning System (GPS) receivers. Aerial photography was used to map the colonies on most of the Buffalo Gap National Grassland (Schenbeck and Myhre 1986). In the southern Great Plains, we conducted an aerial survey to locate colonies on the Comanche, Kiowa, and Rita Blanca National Grasslands during 8–11 June 1998, and later used GPS receivers to map these colonies.

We defined active colonies as those showing black-tailed prairie dog activity throughout the entire burrow system or in part of the burrow system. An inactive colony showed no black-tailed prairie dog activity but retained an intact burrow system and, thus, the potential for Burrowing Owl nesting.

We assessed occurrence of Burrowing Owls on active and inactive black-tailed prairie dog colonies at all National Grassland units containing colonies (Table 1), except Oglala and two National Forest units in Nebraska that are largely grassland with 28 ha of colonies. We determined the presence of owls within each colony through visual observation (binoculars and spotting scopes) from vantage points and by walking or driving through colonies. We spent 20–60 min in each colony between 0600–2000 H. To determine nest occupancy, we looked at burrow mounds for excrement, prey remains, food pellets, eggshell fragments, and feathers (California Burrowing Owl Consortium 1997).

RESULTS

There are 17 075 ha of black-tailed prairie dog colonies on National Grasslands, representing 1.09% of the total National Grassland land base (1 556 048 ha). The percentage of the land-base occupied by black-tailed prairie dog colonies (active + inactive) within National Grasslands ranged from 0% on Cedar River to 3.26% on Thunder Basin (Table 1). Four-hundred forty-four (76%) of 582 colonies examined were active with black-tailed prairie dogs. Comanche and Buffalo Gap had the largest number of the remaining 138 inactive colonies. These colonies were inactive due to sylvatic plague and poisoning. We observed Burrowing Owls at 322 (55%) of the 582 colonies: 307 (69%) of the 444 active colonies had owls and 15 (11%) of the 138 inactive colonies had owls (Fig. 2).

On northern Great Plains National Grasslands (Pawnee, Thunder Basin, Buffalo Gap, Fort Pierre, Grand River, and Little Missouri), 330 (87%) of the 378 colonies examined were active and 48 (13%) were inactive. Burrowing Owls occurred on 196 (59%) of the active colonies and 12 (24%) of the inactive colonies. Most of the inactive colonies were those recently poisoned on the Fall River ranger district of the Buffalo Gap. One colony on Fort Pierre appeared to be inactive because of intensive shooting, and colonies on Pawnee may

Table 1. Black-tailed prairie dog colonies and Burrowing Owl surveys on Great Plains National Grasslands.

National Grassland	Size (ha)	Habitat Occupied by Prairie Dogs		% Colonies Surveyed[a]	Survey Date
		ha	% Total		
Little Missouri	462 705	1050	0.23	64	14–30 Aug.
Cedar River	2 723	0	0.00	—	—
Grand River	62 717	643	1.03	100	13–16 July
Fort Pierre	46 941	291	0.61	100	2–24 June, 6–10 July
Buffalo Gap	241 666	5370	2.22	82	June–July
Thunder Basin	226 688	7381	3.26	68	15 June–15 July
Oglala	38 234	300	0.78	0	—
Nebraska[b]	36 488	28	0.07	0	—
McKelvie[b]	46 966	0	0.00	—	—
Pawnee	78 127	296	0.38	100	7 July–11 Aug.
Comanche	176 181	556	0.31	100	15–26 June
Cimarron	43 776	521	1.19	100	29 June–5 July
Kiowa	55 205	248	0.45	100	29 June–1 July
Rita Blanca	37 631	391	1.04	100	29 June–1 July

[a] Colonies surveyed by observing from nearby vantage points (all units) and also by driving (Thunder Basin) or walking (nine other units) through colonies.

[b] Units of the Nebraska National Forest (largely grassland).

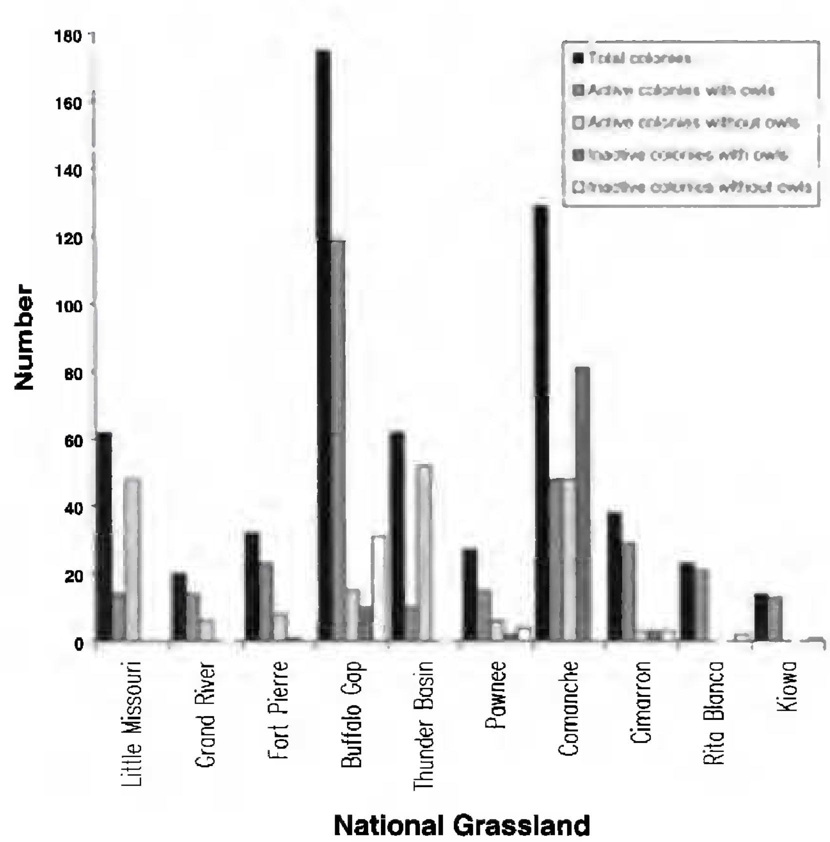

Figure 2. The number and activity status of black-tailed prairie dog colonies observed with and without breeding Burrowing Owls during 1998 at black-tailed prairie dog colonies on Great Plains National Grasslands.

have been inactive because of sylvatic plague. The percentage of colonies occupied by Burrowing Owls ranged from 16% on Thunder Basin to 75% on Grand River.

On southern Great Plains National Grasslands (Cimarron, Comanche, Kiowa, Pawnee, and Rita Blanca), 114 (56%) of the 204 colonies examined were active and 90 (44%) were inactive. Colonies destroyed by sylvatic plague on Commanche accounted for 90% of the inactive colonies. Burrowing Owls were detected on 111 (97%) of the active colonies and three (3%) of the inactive colonies. The percentage of colonies occupied by Burrowing Owls ranged from 37% on the Comanche to 93% on the Kiowa.

DISCUSSION

Burrowing Owls appear to prefer active black-tailed prairie dog colonies (Butts 1973). Burrowing Owls on National Grasslands were more commonly present in active colonies than in inactive colonies (Fig. 2), and tend to be more common in active colonies than in areas containing badger burrows (Desmond 1991, Desmond and Savidge 1996). Colonies destroyed by poisoning or plague harbor a declining number of breeding pairs of owls in successive years. In the absence of black-tailed prairie dog activity, burrows fill in and become unusable to the owls. Furthermore, predation rates on the owls are higher at abandoned black-tailed prairie dog colonies than at active colonies (Desmond et al 2000).

There is no apparent explanation for the low percentage of black-tailed prairie dog colonies containing Burrowing Owls on Thunder Basin (16%; Fig. 2). M. Desmond (unpubl. data) surveyed Thunder Basin black-tailed prairie dog colonies in 1995 and saw no Burrowing Owls. Late survey dates (August) may explain the low percentage (22%) of colonies observed with Burrowing Owls at the Little Missouri.

Our data indicate that Great Plains National Grasslands provide a limited number of black-tailed prairie dog colonies, and thus, limited breeding habitat for Burrowing Owls (Table 1). Modeling of habitat potential (based upon soils, slope, and vegetation) on northern Great Plains National Grasslands indicates that habitat potentially-suitable for prairie dogs comprises >70% of each grassland; however, only 1.9% of this potential habitat is currently occupied by black-tailed prairie dog colonies (USDA Forest Service unpubl. data). Modeling of southern Great Plains National Grasslands likely will indicate that most of those grasslands are also potential habitat for prairie dogs.

Availability of burrows is extremely important for the long-term viability of the Burrowing Owl population (Zarn 1974, Desmond et al. 1995, Desmond and Savidge 1996). National Grasslands and other federal lands represent 1% of the U.S. Great Plains. National Grasslands typically are fragmented, making reestablishment of extensive colonies (e.g., Merriam 1902) difficult without land exchange and consolidation. The Burrowing Owl is a sensitive species for which population viability is a concern, as evidenced by declines in population size and availability of habitat, and the consequent reduction in the species' distribution.

The United States Fish and Wildlife Service (2000) determined that the black-tailed prairie dog warrants listing as a threatened species under the ESA. This should induce land management agencies to maximize their efforts to protect and restore black-tailed prairie dog colonies. National Grasslands are part of the U.S. National Forest System and are administered in compliance with the ESA, National Forest Management Act, National Environmental Policy Act, and other acts. In the past, colonies have been poisoned on National Grasslands to the same extent as those on private land (Roemer and Forrest 1996). Poisoning has ended on National Grasslands, and management plans for northern Great Plains National Grasslands recommend increasing black-tailed prairie dog colonies (USDA Forest Service 2001). National Grasslands could serve as core reserves for black-tailed prairie dogs and associated declining species, including the Burrowing Owl (Wuerthner 1997).

ACKNOWLEDGMENTS

We thank National Grassland staff for field assistance, and Denver Holt, Robert Murphy, and Troy Wellicome for useful comments on an earlier version of this manuscript.

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STATUS OF THE BURROWING OWL IN NORTH DAKOTA

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Abstract.—The Western Burrowing Owl (*Athene cunicularia hypugaea*) was among breeding birds characteristic of North Dakota's vast presettlement mixed-grass prairie, but now seems rare or absent in much of its former breeding range in the state. We assessed the Burrowing Owl's current breeding range in North Dakota and quantified occurrence of the owl where it was most common 15–30 yr ago: the Missouri Coteau and adjoining Drift Plain in central and northwestern North Dakota, and black-tailed prairie dog *(Cynomys ludovicianus)* colonies in southwestern North Dakota. Burrowing Owls were detected at 23–60% of prairie dog colonies surveyed during 1994–99 (N = 25–89 colonies surveyed/yr), which was lower than that reported for the owl at prairie dog colonies across most other states in the Great Plains. During 1995–98, we annually detected 0–3 owl pairs/100 km^2 on a 20% sample of a 840-km^2 survey area in each of central and northwestern North Dakota. In 1998, we also searched intensively for Burrowing Owls within 0.5 km of nest-sites that had been occupied in northwestern North Dakota for at least one yr during 1976–87; we detected an owl at only one (3%)of 38 such areas. East and north of the Missouri River in North Dakota, breeding Burrowing Owls have changed from fairly common or uncommon to rare in the best potential habitat that remains and have disappeared from the eastern one-third of the state; populations apparently fell sharply during the last 5–15 yr. In southwestern North Dakota, the owl's current population trend is unclear but probably is tied closely to prairie dog abundance, which may still be declining.

Key Words: *Burrowing Owl;* Athene cunicularia hypugaea; *breeding range; breeding population trends; Great Plains; mixed-grass prairie; nesting habitat; North Dakota.*

Estado del Búho Cavador en Dakota del norte

Resumen.—El Búho Cavador Occidental (*Athene cunicularia hypugaea*) estaba entre las aves reproductoras características de las vastas praderas de gramíneas mixtas pre- asentamiento en Dakota del Norte, pero ahora parece raro o ausente en la mayoría de su antiguo rango de reproducción en el estado. Nosotros evaluamos el rango reproductivo actual del búho cavador en Dakota del Norte y cuantificamos la ocurrencia de búhos donde este fue mas común 15–30 años atrás en las planicies del Missouri y el plano de drenaje adyacente en el centro y Noroeste de Dakota del Norte, y en colonias de perros de la pradera de cola negra *(Cynomys ludovicianus)* en el sur occidente de Dakota del Norte. Los Búhos Cavadores fueron detectados en 23–60% de las colonias de perros de la pradera estudiadas durante 1994–99 (N

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= 25–89 Colonias estudiadas/año) las cuales fueron mas bajas que lo reportado para el búho en colonias de perros de la pradera a través de la mayoría de otros estados en las Grandes Llanuras. Durante 1995–98, detectamos anualmente 0–3 parejas de búhos/100 km^2 en un 20% de muestra en cada área de estudio de 840-km^2 del centro y Noroeste de Dakota del Norte. Además en 1998, buscamos intensivamente a los Búhos Cavadores dentro de 0.5 km de los sitios nido que habían sido ocupados en el Noroeste de Dakota del Norte por lo menos un año durante 1976–87; detectamos un búho en solo una (3%) de 38 de tales áreas. En el este y norte del río Missouri en Dakota del Norte, las parejas reproductoras de búhos han cambiado de medianamente comunes o poco comunes a raras en el mejor hábitat potencial que permanece y han desaparecido del tercio oriental del estado; aparentemente las poblaciones cayeron abruptamente durante los últimos 5–15 años. En el sudoeste de Dakota del Norte, la actual tendencia poblacional de los búhos no es clara pero probablemente esta estrechamente ligada a la abundancia de perros de la pradera, la cual puede estar aun en declive.

[Traducción de Victor Vanegas y César Márquez]

The Western Burrowing Owl (*Athene cunicularia hypugaea*) was among avifauna characteristic of the northern Great Plains (Coues 1874, Stewart 1975), but its population has declined substantially, at least in parts of the region. It recently has been extirpated from Manitoba and a widespread, severe decline in Saskatchewan continues unabated (Wellicome and Haug 1995, De Smet 1997). The estimated population in Alberta has been nearly halved since 1978 (Wellicome 1997). In the Dakotas, Nebraska, eastern Montana, and eastern Wyoming, its population status is less well-known. Little effort has been made to monitor these Burrowing Owl populations, although many resource personnel suspect the owl is declining and consider it as a "watch" or Special Concern Species (Marti and Marks 1989, Martell 1991). Assessments of population trends in these states are needed to gauge the extent of the regional decline suggested by data from Canada, and to help identify contributing factors and appropriate conservation actions.

Our goal was to evaluate the status of the Burrowing Owl in North Dakota. Specific objectives were to: (1) determine abundance and population trend in areas that appear to offer the best remaining habitat for this species in the state,(2) determine land-use changes and occurrence of the owl at nesting areas occupied during 1976–87 in northwestern North Dakota, and (3) summarize historical and other information on the distribution and abundance of Burrowing Owls in North Dakota and on changes in the species' habitat.

Study Areas and Methods

North and east of the Missouri River in North Dakota, Burrowing Owls mainly inhabit grazed, native prairie within colonies of Richardson's ground squirrels (*Spermophilus richardsonii*; Stewart 1975:157, Konrad and Gilmer 1984). To survey Burrowing Owl abundance in this region, we selected two areas where nest records and published works during the 1970s and 1980s suggested the owl was most likely to be found (Stewart 1975:157, Konrad and Gilmer 1984, Price et al. 1995:92, U.S. Fish Wildl. Serv. [FWS] unpubl. data): western Divide County and central Kidder County, in extreme northwestern and central North Dakota, respectively (Fig. 1). The topography of Divide County (3650 km^2) is mostly rolling, with loamy soils derived from glacial till. Before the 1900s, the county was mixed-grass prairie but now only about 20% of the original native prairie remains (Nat. Resour. Conserv. Serv. and FWS unpubl. land cover data), and, typically, this is grazed by cattle on an annual basis. Cropland (mostly small grains) covers 67% of the county. The rest is mainly wetlands (8%), and hay land and pasture planted with tame (i.e., nonnative) grasses and forbs (4%). Kidder County (3705 km^2) has much more native prairie (50%) and less cropland (32%) than Divide County. Most of the rest of Kidder County is wetland (14%), and tame hay land and tame pasture (3%). A glacial outwash plain, characterized by sandy loam soils, covers most of

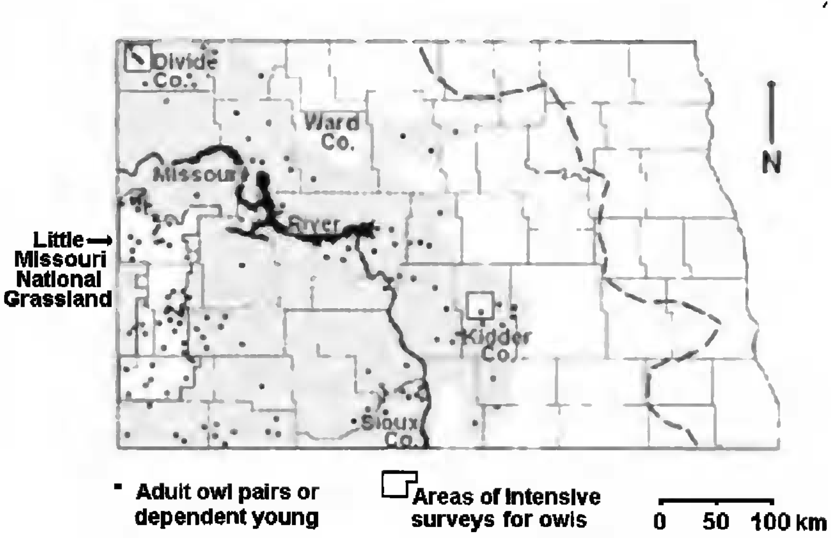

Figure 1. Breeding range of the Western Burrowing Owl in North Dakota. Stippled area is current range (1990s), based on intensive surveys (survey areas indicated) plus records of pairs and adults with dependent young solicited from resource personnel and public (black dots). Approximate eastern limit of breeding range during the 1950s through early 1970s (dashed line) is based on records in Stewart (1975:158). The historical (pre-1880s) breeding range comprised nearly the entire state.

Kidder County (Bluemle 1977). Annual precipitation for Divide and Kidder counties averages 33 and 43 cm, respectively.

In each of western Divide County and central Kidder County, we selected a 840-km^2 study block based on township boundaries (three townships × three townships; Fig. 1) Within the blocks, 252 quarter-section (65-ha) plots were randomly selected for a 20% survey of each block. Nesting Burrowing Owls in nearby southern Saskatchewan are not found on 65-ha survey plots with <4 ha of grassland cover (E. Wiltse unpubl. data). Therefore, we calculated crude density two ways: (1) we assumed no nesting Burrowing Owls inhabited plots with <4 ha of grassland cover and entered zero owls observed for such plots in the database, then used all plots (N = 252) as a basis for density estimate; (2) we only used plots with suitable habitat (≥4 ha grassland cover; N = 118) as a basis for density estimate. Croplands enrolled in the federal Conservation Reserve Program (CRP) are seldom used by nesting Burrowing Owls (Johnson and Schwartz 1993) probably because they are covered with much taller (>50 cm), denser vegetation than that used by the owl for nest sites (Dechant et al. 1999). Thus, we considered CRP to be qualitatively similar to cropland (i.e., unsuitable for the owl).

Our protocol for surveying Burrowing Owls followed that used by Shyry et al. (2001) in Alberta, except that we used a single observer and centered our 65-ha survey plots on section lines, which were open to public travel. Surveys were conducted in early to mid-morning (0600–1100 H CST), during spring (late April–early May) or summer (July–early August), 1995–98. Surveys were not conducted when winds exceeded 20 km/hr, when temperatures were more than 29°C, or when rain prevailed. A vantage point, usually the highest point near the plot center, was used so that most, or all, of a plot could be viewed from one location. Each plot was observed for 5 min, using 10 × 40 binoculars and a 20× spotting scope. A recording of a male Burrowing Owl's primary courtship call was then broadcast in the four cardinal directions for 5 min (Haug and Didiuk 1993), using a Johnny Stewart Wildlife Caller (model #MS512). Observations continued another 5 min after broadcasting ceased. Thus, total observation time at each plot was 15 min. Parts of some survey plots were not visible due to topography; we estimated the area that was not visible on each plot and subtracted it from the total ha searched (J.K. Schmutz unpubl. data).

In addition to these surveys over broad areas of Divide and Kidder counties, we intensively searched for Burrowing Owls in specific areas of northwestern North Dakota where FWS personnel had earlier noted nests incidental to other work (5–18 owl nests recorded/yr, 1976–87 [FWS–Crosby, ND unpubl. data]). We searched for Burrowing Owls at these historical nesting areas (i.e., within 0.5 km of the original nest sites) during mid-May through June 1998. Our sample was limited to 38 mutually exclusive nesting areas for which precise nest-site locations were available: 35 were in Divide County and three were in adjacent Burke County. In each nesting area, we traversed parallel transects spaced every 50 m throughout all habitats except cropland and CRP land, investigating all potential burrows and perch sites for Burrowing Owl sign (e.g., pellets, whitewash). An index of Richardson's ground squirrel abundance was obtained by tallying numbers of active burrows within 10 m of either side of each transect. We also measured change in native prairie area (ha) in each historical nesting area during the past ca. 25 yr by comparing current (1998) area to that on aerial photographs (1:7900) taken in 1969. We used a paired t-test to evaluate the ca. 25-yr change in native prairie area, and Spearman rank correlation to examine the relationship between the ground squirrel index and ha of native prairie in historical nesting areas during late spring 1998

West and south of the Missouri River in North Dakota, nesting Burrowing Owls inhabit mainly black-tailed prairie dog (*Cynomys ludovicianus*) colonies (Stewart 1975 157). In this southwestern region of the state, we searched for Burrowing Owls at prairie dog colonies within the Little Missouri National Grassland (LMNG), a 8620-km^2 expanse of rolling mixed-grass prairie and rugged badlands in Billings, Slope, Golden Valley, and McKenzie counties (Fig. 1). About 62% of the area within the LMNG boundary is public (87% USDA Forest Service–National Grassland, 8% state-owned, 5% National Park Service). Roughly 80% of the area is native prairie that is used chiefly for livestock grazing. Other land uses include dryland farming (small grains), hay production, oil production, and a 280-km^2 national park. The Little Missouri River drainage is the dominant topographic feature. Prairie dog colonies (<1% of area; $\bar{x}$ area = 10.9 ha, range = 0.1–86.0 ha, N = 96; USDA For. Serv. unpubl. data) typically are on broad expanses of gently sloping, clay-loam soils. Many are surrounded by sparsely vegetated, steep slopes of clay, scoria, and shale that is characteristic of North Dakota's Badlands (Bluemle 1977). Vegetation within prairie dog colonies typically is closely cropped, dry mixed-grass prairie. Nearly all prairie dog colonies we surveyed were on public lands. Mean annual precipitation in the area is ca. 36 cm.

Several surveys for Burrowing Owls were conducted in southwestern North Dakota during the 1990s, including those by other investigators (Table 1). During 1996, we repeated an early-May search that was originally conducted on prairie dog colonies in 1991 by De Smet et al (1992). We also randomly selected 10 of the colonies that were occupied in 1991 (De Smet et al. 1992) and annually surveyed each for Burrowing Owls during early July 1995–98. In July 1999, we surveyed nearly all prairie dog colonies within LMNG. Each prairie dog colony was viewed with binoculars and a spotting scope for 0.5–2.0 hr. We viewed from remote vantage points outside the colony to avoid disturbing owls. Recorded calls of Burrowing Owls were not used. We surveyed owls on prairie dog colonies during suitable mornings (i.e., wind <20 km/hr, temperature <30°C, no fog or precipitation). We sometimes also surveyed owls in late evenings.

To augment our information on the Burrowing Owl's breeding range in North Dakota, we used mail, e-mail, telephone, and field contacts during 1995–99 to query university staff, resource personnel, birders, ranchers, and others familiar with the species. We sought current (1990s) records of territorial owl pairs or adults with dependent young in each county and year. A poster campaign and mail-in form also was used under auspices of a state nongame wildlife program to encourage volunteers to report observations of nests and owls.

RESULTS AND DISCUSSION

Northwestern North Dakota. We detected few or no Burrowing Owls in surveys of western Divide County (Table 1). The maximum annual density observed was 3.2 pairs/100 km^2 or roughly three pairs/township, recorded during a spring survey (1998; the maximum estimated density, based on total ha of suitable habitat, was 7.2 pairs/100 km^2). This low density was similar to that recently noted 50 km northwest of Divide County near Weyburn (E. Wiltse unpubl. data), which is part of the large region of Saskatchewan where the owl has declined severely (Wellicome and Haug 1995).

Stewart (1975) considered Burrowing Owls to be fairly common on the northwestern Drift Plain, which extends through Divide County. During 1976–87, FWS staff also noted many Burrowing Owl nest sites incidental to their work in Divide and two adjacent counties (Table 1). However, during the late 1980s–1990s, Burrowing Owl abundance declined sharply in the area; each year, Burrowing Owl pairs were seldom observed, even though observers changed little and efforts to locate the owls increased.

During 1998, we were able to detect Burrowing Owls at only 3% of historical nesting areas surveyed in northwestern North Dakota (Table 1). Nest-site fidelity is variable in migratory populations of Burrowing Owls, and abundance is likely underestimated by surveys that focus on previously-used nest sites (Rich 1984). This potential bias was minimized in our study, however, because we searched up to 0.5 km from nest sites. Also, nest sites may be more likely to be reused after several years of nonuse (Rich 1984). Absence from historical nesting areas was consistent with the low abundance evident from our random survey of western Divide County and the scarcity of incidental observations in the area since the mid-1980s. A decline in Burrowing Owl abundance in western Divide County may stem from recent loss of grassland habitat and associated burrowing rodents. Indeed, native prairie within 0.5 km of historical Burrowing Owl nest sites declined an average of 33% since the 1960s (1969 vs. 1998 [$\bar{x} \pm$ SE]: 15.5 $\pm$ 2.5 ha vs. 9.5 $\pm$ 2.2 ha; paired $t = 3.00$, df $= 37$, $P = 0.006$ after data were log-transformed to meet normality assumption). This change was due to conversion to cropland. We detected active Richardson's ground squirrel burrows at 11 (29%) historical nesting areas in 1998. Nearly all ground squirrel burrows were in heavily-grazed native prairie; the number of burrows and area (ha) of native prairie within 0.5 km were correlated ($r_s = 0.62$, $P = 0.002$, $N = 24$). Although breeding habitat available to Burrowing Owls has declined in western Divide County, we observed what appeared to be suitable but unoccupied habitat at historical nesting areas and elsewhere, as noted in the prairie region of Canada (Wedgwood 1976, Wellicome and Haug 1995).

Central North Dakota. Breeding Burrowing Owls were fairly common in the mid-1980s in parts of Ward County in north-central North Dakota (Fig. 1), but have disappeared since (Table 1). We were unable to find any Burrowing Owls during an intensive survey of central Kidder County in July 1998, even though the species was fairly common in the area in the late 1970s (Table 1). As in northwestern North Dakota, a decline in numbers of the owl was evident in Kidder County since the mid-1980s (Table 1). Timing of these population changes parallels that of the steep decline of Burrowing Owls in Saskatchewan (Wellicome and Haug 1995).

Southwestern North Dakota. De Smet et al. (1992) detected Burrowing Owls at nearly one-half of active prairie dog colonies surveyed within LMNG during early-May 1991 (Table 1), but they believed owl presence was underestimated due to cold, windy, snowy weather at the time of the survey. In May 1996, we found owls at about one-fourth of the same prairie dog colonies surveyed by De Smet et al. (1992), although many of the colonies no longer existed or were no longer active (i.e., used by prairie dogs). Considering active colonies alone ($N = 23$ in 1996), Burrowing Owl occurrence was fairly similar between the two surveys (45% and 39%, respectively).

Other surveys of Burrowing Owls in southwestern North Dakota were conducted after May (Table 1). These may not be directly comparable to May surveys due to temporal changes that influence the species' detectability (e.g., some owl pairs fail in nesting and may abandon nest sites by early summer). Among surveys during summer, Burrowing Owl occurrence was highest during July (1999) surveys (Table 1), probably because owls with recently emerged young tend to be conspicuous at that time of year. Regardless, Burrowing Owls were detected on up to approximately one-half of prairie dog colonies surveyed in spring or summer by

Table 1. Population status and breeding range of the Burrowing Owl in North Dakota: a summary of relevant historical and current (1990s) information.

AREA	DATA TYPE	YEARS	COMMENTS AND CONCLUSIONS REGARDING BURROWING OWLS	SOURCE
Statewide	Literature review	late 1800s	Breeding in nearly all of the state	Stewart 1975:157
	Reports from experts and general public; surveys	1950s to early 1970s	Breeding in all but eastern one-fifth of the state	Stewart 1975:158
	Reports from experts and general public; surveys	1990s	Breeding limited to approximately western one-half of state (see Fig. 1)	This study
	North American Breeding Bird Survey	1966–79	No clear population trend in state	J.R. Sauer et al. public comm.
	North American Breeding Bird Survey	1980–96	Declining 10% per year in state	J.R. Sauer et al. public comm.
	Statewide survey of breeding birds	1967, 1992–93	Detected each year on 2% of 128 randomly selected, 65-ha survey plots	Igl et al. 1999
North-central (Ward County)	County breeding bird atlas	mid-1980s	Breeding confirmed on 11 of 57 townships; owls associated with heavily-grazed, mixed-grass prairie	G. Berkey and R. Martin unpubl. data
	Searches for the owl where documented in mid-1980s county bird atlas, and other likely habitat (i.e., grazed prairie)	1990s	Zero owl pairs detected in county, even though most habitat where owls were observed in mid-1980s appears intact	G. Berkey and R. Martin unpubl data
South-central (Kidder County)	Surveys and reports	1950s to early 1970s	Fairly common in Kidder County outwash plain	Stewart 1975:157
	Observations incidental to general survey of breeding raptors	1977–79	Found 45 nests on Missouri Coteau especially Kidder Co. outwash plain	Konrad and Gilmer 1984
	Searches every 1–2 yr in nesting areas documented by Konrad and Gilmer (1984), and in other likely habitat (e.g., heavily-grazed, mixed-grass prairie)	late-1980s to mid-1990s	Burrowing Owls increasingly rare, difficult to find during the 1990s	P. Konrad unpubl data
	Intensive surveys	1998	Zero owl pairs on 168 km^2 of Kidder County outwash plain (July)	This study
Northwestern (mainly Divide County)	Surveys and reports	1950s to early 1970s	Fairly common in northwestern Drift Plain	Stewart 1975:157
	Incidental observations	1976–87	Five to 18 nest-sites noted annually	unpubl. data[a]
	Incidental observations	1990s	Zero to two nest-sites noted annually	unpubl. data[a]
	Survey of areas within 0.5 km of nest-sites used $\geq$1 yr during 1976–87	1998	Detected owls at one of 38 (3%) of the historical (1976–87) nesting areas	This study
	Intensive surveys	1995–98	0–3 owl pairs/100 km^2, western Divide County (May and July)	This study

Table 1. Continued.

AREA	DATA TYPE	YEARS	COMMENTS AND CONCLUSIONS REGARDING BURROWING OWLS	SOURCE
Southwestern	Literature review	late 1800s, early 1900s	Strong affinity for prairie dog towns; common there	Stewart 1975:157
	Surveys and reports	1950s to early 1980s	Uncommon to fairly common locally in much of area	Stewart 1975:157, Seabloom et al. 1978; J.P. Ward, L.R. Hanebury, and R.L. Phillips unpubl. data
	Survey of owls on prairie dog towns	1991	45% occurrence on 33 towns on LMNG,[b] in May (poor survey weather)	De Smet et al. 1992
	Survey of owls on prairie dog towns	1994	28% occurrence on 25 towns, Billings County portion of LMNG, June–August	Davidson et al. 1995
	Resurvey of owls on prairie dog towns surveyed by De Smet et al. (1992)	1996	27% occurrence on 33 towns on LMNG, May (10 of the towns no longer existed or were unused by prairie dogs)	This study
	Survey of owls on prairie dog towns	1998	23% occurrence on 62 towns, LMNG, August (late survey date)	Sidle et al. 2001
	Survey of owls on prairie dog towns	1999	49% occurrence on 89 towns, LMNG, July	This study
	Survey of owls on prairie dog towns	1999	60% occurrence on 10 towns in northern Sioux County, July	K. Haas unpubl. data

[a] U.S. Fish Wildl. Serv. unpubl. data files, Crosby, North Dakota.
[b] LMNG = Little Missouri National Grassland, a 8620-km^2 expanse of mostly publicly-owned prairie and badlands, covering most of Billings, Slope, and McKenzie counties and eastern Golden Valley County.

us or others in southwestern North Dakota. In contrast, Sidle et al. (2001) observed Burrowing Owls at >90% of active prairie dog colonies on National Grasslands from South Dakota to Texas during summer 1998. We are uncertain why Burrowing Owls occur relatively infrequently at prairie dog colonies in North Dakota. We lack historical occurrence data of the same type for comparison; we have only notes and nest records that indicate Burrowing Owls were uncommon to fairly common locally in southwestern North Dakota, as recently as the early 1980s (Table 1). Perhaps Burrowing Owls simply occur less frequently in prairie dog colonies that are relatively far from the center of the owl's breeding range in western North America.

Ten prairie dog colonies occupied by Burrowing Owls in 1991 (De Smet et al. 1992) were randomly selected by us for yearly searches during July 1995–98. We found 5–7 of the colonies occupied annually; all but one colony was occupied in at least 1 of 4 yr. This small sample suggests that, in southwestern North Dakota, active prairie dog colonies used recently (<5 yr) by Burrowing Owls are more likely to be reoccupied by the species than prairie dog colonies chosen at random. Consistency in occupancy of prairie dog colonies may relate directly to colony size, as do numbers of owls in Nebraska (Desmond and Savidge 1996). Furthermore, Burrowing Owls at small (<35 ha) colonies in southwestern North Dakota seem less secretive than owls on larger colonies, perhaps because the former are infrequently disturbed by humans; shooters of prairie dogs tend to overlook small colonies (S. Gomes and C. Grondahl pers. observ.).

The current population trend of Burrowing Owls in southwestern North Dakota is unclear but likely tied with that of black-tailed prairie dogs. Prairie dog colonies are largely restricted to two major grasslands: LMNG (including some colonies on nearby national park, state, and private lands) and extensive tribal lands in Sioux County (Fig. 1). Remaining landscapes in the southwestern region are dominated by cropland and have few prairie dog colonies, which are mostly isolated on grassland fragments. During 1939–72 the total area of prairie dog colonies on 5100 km^2 of LMNG and associated public and private lands declined 93% (5512 ha to 403 ha; Bishop and Culbertson 1976). Prairie dog colonies currently occupy only 0.2% of 4616 km^2 of federal National Grassland within LMNG, even though habitat models suggest 71% of the land is suitable for prairie dog colonies (USDA For. Serv. unpubl. data). Remaining colonies in southwestern North Dakota are mostly small (<35 ha) and may support poorer reproductive success per Burrowing Owl pair than larger colonies because, as prairie dog colonies become increasingly isolated and fragmented, Burrowing Owls experience increased predation risk and their numbers decline (Desmond et al. 2000). Prairie dogs were added to the North Dakota list of noxious pests in 1995, requiring private landowners to try to eradicate prairie dogs on their lands (North Dakota Century Code 63–01.1–02, subsection 12). However, new management plans for LMNG may lead to substantial overall increases in prairie dog colony area.

State-wide: Breeding Range and Habitat. No territorial pairs of Burrowing Owls have been reported from approximately the eastern one-half of North Dakota since the 1980s (Fig. 1). In the late-1800s, Burrowing Owls nested throughout the state, and they persisted as breeding birds through much of eastern North Dakota as recently as a quarter-century ago (Table 1). A range contraction in eastern North Dakota is consistent with the extirpation of Burrowing Owls from adjacent Manitoba and Minnesota (De Smet 1997, Martell et al. 2001). The contraction also agrees with our evidence of declining Burrowing Owl populations within selected counties east of the Missouri River.

According to data from the North American Breeding Bird Survey (BBS), Burrowing Owls exhibited no clear population trend in North Dakota during 1966–79, but the species declined at an average rate of 10% per yr during 1980–96 (route-regression analysis, $P < 0.01$; Sauer et al. 1997). However, these trends should be interpreted cautiously because the species was detected rarely on BBS routes ($\bar{x} = 0.2$ detection/route/yr; 1980–96). In the Northern Great Plains region, BBS data suggest Burrowing Owls are declining in the Glaciated Missouri Plateau physiographic region (approximates the Missouri Coteau; 1980–96; $P = 0.03$), but not in the Great Plains Roughlands (south and west of the Missouri River; $P = 0.44$).

A recent decline in Burrowing Owls east of the Missouri River might be explained, in part, by reduced abundance of Richardson's ground squirrels. The rodent prefers open native prairie that is grazed short (Jones et al. 1983:138). This species was fairly common and widespread in central Kidder County 15–20 yr ago (P. Konrad pers. comm.), but during July 1998 we seldom observed Richardson's ground squirrels, their burrows, or native prairie that was grazed short. We suspect habitat appropriate for nesting Burrowing Owls has decreased in Kidder County due to above-average annual precipitation since 1993 (National Weather Service data) and decreased sheep ranching. Although numbers of cattle in Kidder County have remained relatively constant since the late 1960s (72 000 ± 7000 head), numbers of sheep have declined during the same time period (20 000 head in the late-1960s to 8000–10 000 since the mid-1970s; North Dakota Agric. Stat. Serv., Fargo unpubl. data).

In North Dakota Burrowing Owls depend on mixed-grass prairie, which dominated the pre-settlement landscape. About 75% of this native habitat has been converted to other land uses, mainly cropland (Samson and Knopf 1994, D. Lenz, North Dakota Nat. Heritage Pgm., Bismarck, ND unpubl data). Losses have been particularly great in the Drift Plain, the largest physiographic subregion in North Dakota. Native prairie continues to decline in quality and quantity due to conversion and fragmentation impacts and to invasion by introduced and woody vegetation (Samson and Knopf 1994). Widespread establishment of tame grass-forb cover on croplands under CRP fails to mitigate these losses for nesting Burrowing Owls and several other grassland bird species, although some grassland bird species significantly benefit from CRP (Johnson and Schwartz 1993). North Dakota has more National Wildlife Refuges than any other state, but Burrowing Owls no longer nest on these lands (FWS unpubl. data), probably because refuge management practices generally favor cover (grasses, forbs, and low shrubs) that is taller and denser than that preferred by the owl (Murphy 1993). Moreover, alterations in prairie landscapes contribute significantly to changes in the composition and distribution of predators that may negatively affect grassland bird species (Sargeant et al. 1993), including Burrowing Owls. Avian predation on Burrowing Owls seems particularly exacerbated by widespread increases in trees due to shelterbelt planting and fire suppression (Clayton and Schmutz 1999).

Although the Burrowing Owl has become rare in most of North Dakota, the species' status has received surprisingly little previous attention. This probably stems from a lack of consensus among biologists across the Great Plains that results from inadequate monitoring. Foremost is the reliance on BBS data, which indicate no clear population trend for Burrowing Owls in the central and northern Great Plains states (approximates FWS Region 6; Sauer et al. 1997). Using this methodology, the trend data may be statistically valid but biologically irrelevant for a species so thinly scattered and difficult to detect throughout its breeding range. Range contractions, however, generally indicate population declines (Wilcove and Terborgh 1984, Krebs 1994). Our data extend the range contraction recently indicated for Burrowing Owls in Canada's prairie region (Wellicome and Haug 1995, De Smet 1997). In North Dakota, the species' status designation is "watch" (declines in distribution and abundance are suspected but unconfirmed; Anonymous 1986). Review of this status designation seems warranted.

Acknowledgments

We dedicate this paper to the memory of Thad L. Fuller (1941–94), who showed exemplary stewardship over Burrowing Owls and other native prairie resources during his tenure as FWS wildlife manager in northwestern North Dakota. Work on Burrowing Owls in northwestern and central North Dakota during 1994–98 was supported jointly by North Dakota Game and Fish Department's (NDGFD) Nongame Program, The Nature Conservancy, FWS–Ecological Services (M. Dryer, M. Olson, and A. Sapa), FWS–Nongame Migratory Bird Program (S. Jones and J. Cornely), and Des Lacs NWR Complex (Project Leaders M. Blenden and F. Giese). T. Fuller, T. Kessler, T Placek, and M. Ellingson collectively gathered nearly 100 incidental nest-site records in northwestern North Dakota during 1976–99, and Kessler and Placek lent logistical support during our surveys in the area. G. Wolf, M Nenneman, and T. Stefanic conducted many owl surveys. Personnel at Long Lake NWR and Chase Lake NWR Complexes lent logistical support for our work in Kidder County. FWS–Habitat and Population Evaluation Team (Bismarck) kindly furnished land use cover maps.

In southwestern North Dakota, Burrowing Owl surveys were conducted on the Little Missouri National Grassland during the late-1990s with help from L. Clough (USDA Forest Service), S. Gomes (NDGFD), and volunteers from the North Dakota Falconers' Association. G Foli and D. Svingen (U.S. Forest Service) graciously helped with several logistical details. K. Haas conducted owl surveys on prairie dog colonies in northern Sioux County during 1999, with partial support from NDGFD

We thank dozens of individuals for reporting Burrowing Owl observations or lack thereof. Many current distribution records were provided by members of the North Dakota Birding Society, and by Northern Prairie Wildlife Research Center staff (USGS-Biological Resources Division), especially L. Igl. We are particularly grateful to G. Berkey, K. De Smet, M. Desmond, D. Hjertaas, G Holroyd, P. Konrad, J. Schmutz, and E. Wiltse for sharing expertise on the owl and advice on techniques. D. Martin kindly provided recordings of Burrowing Owl territorial calls used in our surveys in Divide and Kidder counties We appreciate helpful input on early manuscript drafts by D. Bruns Stockrahm, P. Konrad, and K. Smith. Critical reviews by K. De Smet, G. Holroyd, L. Igl, M. Restani, and T. Wellicome greatly improved the final manuscript draft.

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J Raptor Res. 35(4):331–336

STATUS AND ATTEMPTED REINTRODUCTION OF BURROWING OWLS IN MINNESOTA, U.S.A.

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Abstract.—Burrowing Owls (*Athene cunicularia*) have been recorded nesting in most of Minnesota's western counties. Considered common in the early 1920s, by the mid-1960s only 9–10 breeding pairs were known with estimates of no more than 20 pairs in the west-central part of the state. Ten breeding records exist for the period 1965–85. In 1984, Burrowing Owls were listed as Endangered by the State of Minnesota. In 1986, we began surveys and site management for nesting Burrowing Owls and experimented with a reintroduction program. From 1986–90, 13 nests were found at eight sites, with a mean reproductive success of 3.5 fledglings/pair. The maximum number of breeding pairs/yr was four. Nest burrows were found in alfalfa fields (37.5%), pastures (37.5%), roadside ditches (12.5%), and fencelines between row crop fields (12.5%). We released 105 wild, preflighted juveniles: nine in 1986, 18 in 1987, 21 in 1988, 27 in 1989, and 30 in 1990. Young owls were kept in hack pens with roofs and sides made from cotton mesh fish netting. Burrows inside each pen and in surrounding fields were available to the owls. Crippled adults were placed in each pen with the juveniles but were not released. We documented eight mortalities, all of which were fledglings recovered in the release area. No owls were found, or reported, after leaving their hack sites. No successful nestings occurred from 1992–98.

Key Words: *Burrowing Owl;* Athene cunicularia; *reintroduction; status; endangered species; Minnesota.*

Estado y reintrocucción fallida de Búhos Cavadores en Minnesota, U.S.A.

Resumen.—Los Búhos Cavadores (*Athene cunicularia*) han sido registrados anidando en la mayoría de condados del occidente de Minnesota. Considerado común a principios de 1920, para la mitad de los 60's únicamente se conocían 9–10 parejas reproductoras con un estimativo de no mas de 20 parejas en la parte oeste-central del estado. Diez registros de reproducción existían para el periodo 1965–85. En 1984, los Búhos Cavadores fueron puestos en la lista de especies en peligro para el estado de Minnesota. En 1986, nosotros iniciamos prospecciones, el manejo de un sitio para anidación de Búhos Cavadores y experimentamos con un programa de reintroducción. De 1986–90, 13 nídos fueron encontrados en ocho sitios, con una media en el éxito reproductivo de 3.5 volantones por pareja. El máximo numero de parejas reproductoras/año fue cuatro. Las cuevas nido fueron encontradas en campos de alfalfa (37.5%), pastos (37.5%), zanjas de carreteras (12.5%) y líneas de cercas entre las filas de los campos de cultivo (12.5%). Nosotros liberamos 105 juveniles previamente adiestrados para volar: nueve en 1986, 18 en 1987, 21 en 1988, 27 en 1989, y 30 en 1990. Los jóvenes búhos permanecieron en encierros de caballos con los techos y los lados cubiertos con mallas de pescar hechas de algodón. Estuvieron disponsibles para los búhos cuevas dentro de cada corral y en los campos circundantes. Los adultos lisiados fueron colocados en cada corral con los juveniles pero no se liberaron. Documentamos ocho muertes, cada una de las cuales fueron volantones recuperados en el área de liberación. Ningún búho fue encontrado, o reportado, después de abandonar sus sitios de encierro. No ocurrió ninguna nidada exitosa de 1992 a 1998.

[Traducción de Victor Vanegas y César Márquez]

Minnesota's western counties are at the eastern edge of the Burrowing Owl's (*Athene cunicularia*) breeding range in North America, excluding the disjunct Florida population (*A. c. floridana,* Haug et al. 1993). The species was first recorded in Minnesota in July 1881, and there are historical nesting

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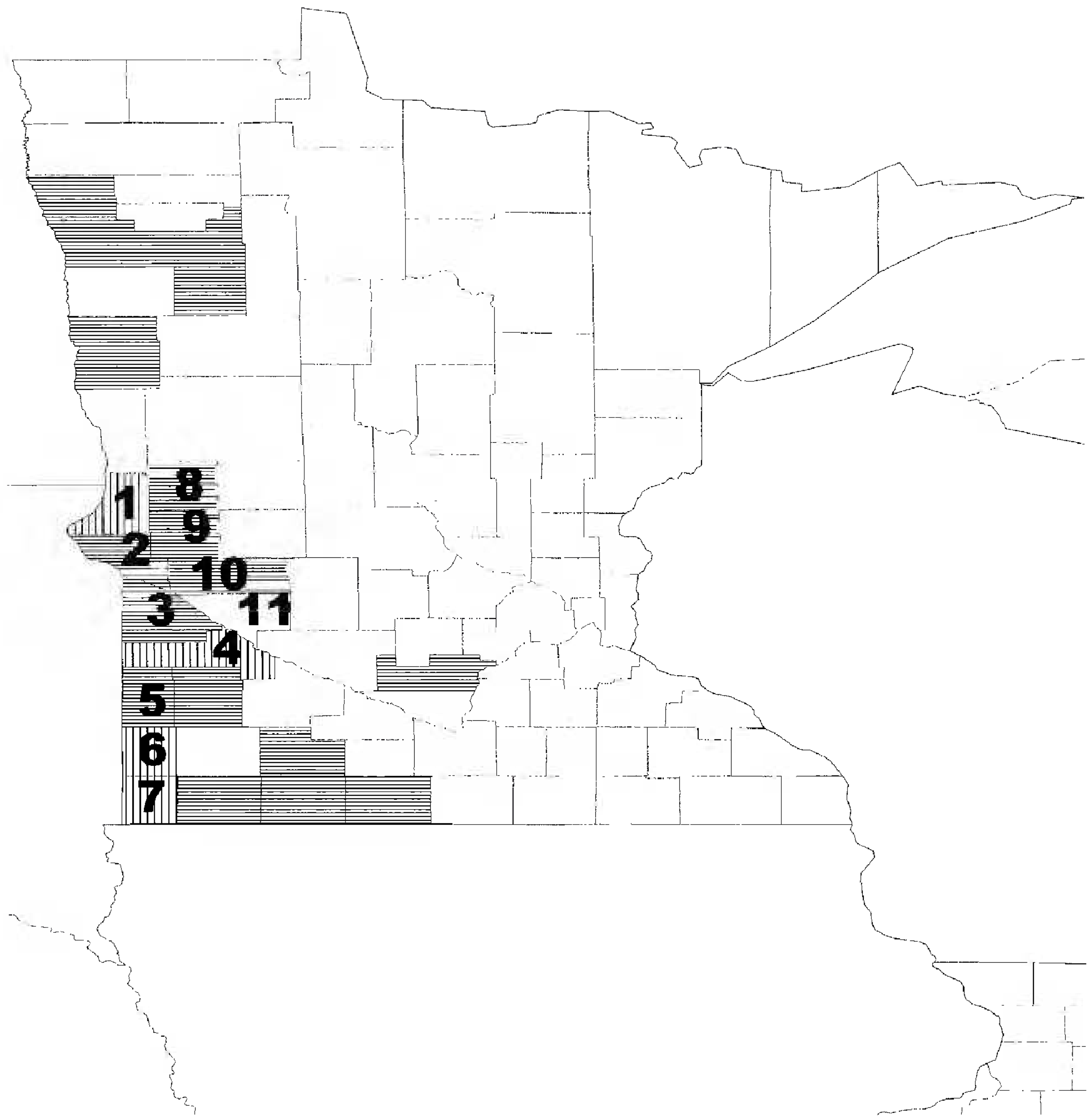

Figure 1. Minnesota counties with historical (1881–1986, horizontal hatch) and modern (1987–91, vertical hatch) Burrowing Owl nesting records. Counties: 1 = Traverse, 2 = Big Stone, 3 = Lac Qui Parle, 4 = Yellow Medicine, 5 = Lincoln, 6 = Pipestone, 7 = Rock, 8 = Grant, 9 = Stevens, 10 = Swift, 11 = Chippewa.

records for most of the state's western counties (Fig. 1). In the early 1920s Burrowing Owls were thought to nest commonly throughout Grant, Traverse, Pipestone, Lincoln, and Lac Qui Parle counties (counties 8, 1, 6, 5, 3; Fig. 1), as well as further north in the Red River Valley (Roberts 1932).

In the mid-1960s, Grant (1965) reported 9–10 breeding pairs in Stevens and Traverse counties, and estimated no more than 20 pairs of owls in the five-county area that included Stevens, Traverse, Grant, Big Stone, and Swift (counties 9, 1, 8, 2, 10; Fig. 1). Grant (1965) suggested the Burrowing Owl was no longer common in that part of the state. We found only 10 Minnesota breeding records for the 20-yr period from 1965–85 (Martell 1990). The species was state-listed as Endangered in 1984 (Coffin and Pfannmuller 1988).

To develop management strategies to recover the species from its endangered status, we began to test reintroduction techniques (Martell 1990) and to survey for nesting Burrowing Owls in Minnesota in 1986. This paper summarizes methods and results of the reintroduction, as well as habitat use, population status, and reproductive performance of Burrowing Owls in Minnesota from 1986–98.

METHODS

Monitoring of Wild Population. To locate nesting Burrowing Owls, we solicited information from the public, conducted surveys in suitable habitat, and searched historical nest sites during the spring and summer of 1986–90. Less rigorous monitoring and public contact continued from 1991–98.

In 1986, bird clubs and conservation organizations were contacted, and television, radio, and newspaper interviews were used to increase public awareness and encourage reporting of Burrowing Owls seen in the state

Table 1. Location, habitat, and number of young fledged at nests of wild Burrowing Owls in Minnesota, 1987–91.

		NUMBER OF YOUNG FLEDGED				
COUNTY	HABITAT	1987	1988	1989	1990	1991
Pipestone	Alfalfa	≥3	≥3	≥3	—	—
Pipestone	Roadside	≥3	—	—	—	—
Rock	Pasture	—	≥2	5	≥2	—
Yellow Medicine	Fenceline	—	≥2	—	—	—
Traverse	Pasture	—	≥2	—	—	—
Rock	Alfalfa	—	—	8	7	—
Rock	Pasture	—	—	2	—	—
Rock	Alfalfa	—	—	—	5	≥2

In 1988, a color poster featuring Burrowing Owls was distributed statewide to solicit nesting reports. During the spring of 1989, 1000 black-and-white posters that requested reports of Burrowing Owls and Short-eared Owls (*Asio flammeus*) were distributed to Minnesota Department of Natural Resources (MNDNR) personnel and posted in public locations throughout western Minnesota. In both 1989 and 1990, 10 000 copies of this poster were mailed to farmers in the southwest region of the state. An additional 10 000 copies were mailed in the northwest region in 1990.

Between 17 May–7 June 1988, a 150-km route was surveyed through Lac Qui Parle, Chippewa, Big Stone, and Stevens counties (counties 3, 11, 2, 9; Fig. 1). This route encompassed the reintroduction area (Martell 1990) and the area where historical concentrations of Burrowing Owls were recorded (Grant 1965). The route was driven between 0600–1000 H, three times/wk. Using binoculars and a 15–60X spotting scope, we searched for owls in fields and along roadsides. In 1989 we surveyed 1000 km of roads in nine southwestern Minnesota counties. All occupied nest sites were visited in years subsequent to their use, and all public reports of owls were checked in all years.

Nest sites were mapped and entered into the State of Minnesota's Natural Heritage database. Land use and ownership were recorded for each nest. We calculated the number of fledglings as the maximum number of prefledged juveniles seen at a burrow, minus known mortality prior to fledging. Reproductive success was measured as the number of young fledged/pair.

Land management focused on protection and enhancement of nesting sites. We encouraged landowners to maintain fields used by nesting owls in their current rotation (e.g., alfalfa), or enroll those fields in federal agricultural set-aside programs. In fall 1989, 24 artificial burrows (Henderson 1984) were placed near natural burrows to provide alternate nest sites for returning pairs of owls or their offspring in future years.

Reintroduction. Young owls were obtained for reintroduction by trapping on black-tailed prairie dog (*Cynomys ludovicianus*) colonies on the Fort Pierre National Grasslands, located approximately 8 km south of Pierre, South Dakota. Juvenile owls were trapped using "Haug traps" (Haug 1985), consisting of a piece of clear Plexiglas attached by a hinge to a 30-cm section of black drainage pipe (10 cm diameter). This was positioned in the burrow entrance with the door opening out, allowing owls to leave but not reenter their burrow. The area above and immediately around the burrow entrance was covered with a chicken wire cage, enabling us to capture the birds without their escaping.

Release sites were located within historical Minnesota nesting range. The sites were available for future Burrowing Owl management needs, allowed us to control unwanted human intrusion during the release, and could be managed and modified to suit the needs of the project. Owls were kept in hack pens made from cotton-mesh fisheries netting (1.5 cm diameter) strung along metal fence poles. Pens were approximately 7.6 m long × 5.5 m wide × 1.7 m high. Wooden artificial burrows (40 cm × 40 cm, Henderson 1984) were placed 0.6 m underground and connected to the surface by a wooden tunnel.

While in the hack pens, owls were fed dead laboratory mice and weanling rats daily. Daily feeding of mice, weanling lab rats, European Starlings (*Sturnus vulgaris*), and House Sparrows (*Passer domesticus*) then continued for 33 d post-release. To protect released juveniles from predation by Great Horned Owls (*Bubo virginianus*), we used adult Burrowing Owls as "parental models," increased the number of burrows around the site, and removed local Great Horned Owls under federal and state permits.

Banding and Marking. Wild and released juveniles were banded with a standard U.S.G.S. band and one red, yellow, or green leg marker (Martell 1990).

RESULTS

Monitoring the Wild Population. Between 1987–91, 14 successful nestings were recorded at eight sites in four counties (Rock, Pipestone, Traverse, and Yellow Medicine, counties 7, 6, 1, 4; Fig. 1) in western Minnesota (Table 1). Four of the eight sites were used only once. The maximum number of nests found within any year was four (1988 and 1989). A minimum of 49 young was produced for a minimum reproductive rate of 3.5 young/pair.

Table 2. Number of Burrowing Owls released, mortality, and number of days seen after release.

YEAR	NO. OF OWLS RELEASED	NO. OF MORTALITIES	MINIMUM NO. OF DAYS SEEN POST-RELEASE
1986	9	3	1.5
1987	18	1	37
1988	21	0	21
1989	27	2	30
1990	30	2	15.5
Total	105	8	

No nesting Burrowing Owls were recorded in Minnesota from 1992 through 1998.

All new nest records between 1987–98 were reported by local citizens or MNDNR personnel responding to posters or personal contacts. No nesting Burrowing Owls were located during road surveys. Fledging occurred during the last two weeks of July. Two adults and one immature bird died during our study: the immature and one adult were killed by collisions with vehicles, and the cause of death for the other adult was unknown.

Land uses at the eight nest burrows were alfalfa fields (37.5%), pastures (37.5%), roadside ditches (12.5%), and fencelines between row crop fields (12.5%; Table 1). Seven of 14 nestings (50%) were in alfalfa fields and produced 32 young (63% of total). All but one of the nests were located on privately-owned land. One pair of owls fledged seven young from an artificial burrow the year after their natural burrow collapsed. The artificial structure was located in the same field, approximately 40 m from the original burrow.

Reintroduction. From 1990–96, we released 105 juvenile Burrowing Owls (Table 2). We documented eight mortalities at or near release sites. With the exception of 1996, almost all birds were seen well past fledging (Table 2). No birds were found or reported after they left their hack sites.

DISCUSSION

Current Status and Reproductive Success. The Burrowing Owl is currently listed as Endangered by the state of Minnesota. The number of nesting owls found from 1987–91 was the highest recorded in Minnesota since the mid-1960s (Grant 1965), but this was likely a result of our intensive searches. Lack of nesting from 1992–98, despite continued interest and monitoring of sites, leaves little doubt that the population is extremely small. Therefore, Endangered status is justified in Minnesota.

Reproductive success recorded during this study (3.5 fledglings/pair) was similar to the historical estimate of 3.8 fledglings/pair for Minnesota (Grant 1965). Our results were also similar to other productivity estimates of 2.2 fledglings/pair in California (Thomsen 1971), 4.0 in North Dakota (Konrad and Gilmer 1984), 4.4 in Saskatchewan (Wedgwood 1976), and 4.9 in New Mexico (Martin 1973). In our opinion, these estimates suggest that Burrowing Owl population size in Minnesota is not limited by reproduction. Other factors, historical and current, probably have caused the population decline.

Reasons for Population Decline. Burrowing Owl populations have declined in other parts of their breeding range, where habitat loss, predation, and pesticides have been identified as important problems (Haug 1985, James and Espie 1997). In Minnesota, the population decline has been attributed to three factors: intensive cultivation of agricultural lands, plowing of native prairie and pastureland, and the decimation of burrowing mammals in the western part of the state (Grant 1965). However, Coffin and Pfannmuller (1988) noted that suitable unoccupied habitat still seemed to exist in the state, a situation also noted for Endangered populations in Canada (De Smet 1997, Schmutz 1997, Wellicome 1997). The use of alfalfa fields by nesting Burrowing Owls in our study indicates that these birds may have some capacity to adapt to agricultural habitats provided that burrows are available.

Lack of suitable nest burrows may also contribute to the population decline in Minnesota. Burrow availability has been suggested as a factor limiting Burrowing Owl populations in other parts of the United States (Coulombe 1971, Zarn 1974). In Minnesota, Burrowing Owls have been reported to nest in burrows abandoned by badgers (*Taxidea taxus*) and Richardson's ground squirrels (*Spermophilus richardsonii*) (Roberts 1932, Grant 1965). We recorded no use of Richardson's ground squirrel burrows during our study, despite the presence of a large colony near the Rock County nest sites (B. Lane pers. comm.). Roberts (1932) stated that holes made by Minnesota's ground squirrels were too small to be used by Burrowing Owls until badgers enlarged them. Badgers may be a critical source of nesting burrows in Minnesota, a situation similar to that reported in Canada (Wellicome

1997) and in the Columbia Basin of Oregon (Green 1983).

Burrow and burrowing mammal (e.g., Richardson's ground squirrels, badgers) management may benefit Burrowing Owls in Minnesota. Artificial burrows are readily accepted by nesting pairs in other parts of their range (Collins and Landry 1977, Wellicome et al. 1997). Promotion of artificial burrow construction through a "Burrowing Owl Trails" program similar to that done for Eastern Bluebirds (*Sialia sialis*) and Wood Ducks (*Aix sponsa*) may benefit this species in Minnesota and in other parts of its range. However, with the current low population levels in Minnesota, location of burrows would be critical to success. Low priority should be given to this effort in Minnesota.

Causes of decline may also operate away from breeding areas. Burrowing Owls are migratory in the northern portion of their range (Bent 1938, Haug et al. 1993). No specific information exists on the migration routes or wintering areas of Minnesota Burrowing Owls. Based on nine band recoveries, Brenckle (1936) described the wintering range of the Northern Plains population as "central Texas and adjoining Oklahoma." Loss of grassland habitat in the wintering range has been suggested as the cause of decline in the midwestern population of Loggerhead Shrikes (*Lanius ludovicianus*) (Brooks and Temple 1990). This possibility also needs to be considered for Burrowing Owls.

Continued monitoring for Burrowing Owls in Minnesota is probably best accomplished through public contact. Landowner reluctance to report owls in some parts of their range (De Smet 1997) may argue against exclusive reliance on this means of locating breeding pairs. Publicity through posters, mailings, and media produced all nest reports during this study and seems to be an effective and efficient method for locating nesting pairs in Minnesota. Field surveys in areas traditionally used by Burrowing Owls were important to establish presence or absence of nesting owls. However, surveys proved ineffective in locating new sites.

Feasibility of Reintroduction. We suggest that reintroducing Burrowing Owls into western Minnesota is not a wise management strategy. The techniques used were successful in getting juvenile birds through the fledging stage, and we documented foraging, burrow use, and successful predator avoidance (Martell 1990), but no released owls returned to breed. Although the numbers of birds released was not large, enough were released to expect some resightings in subsequent years. A return rate of 14% for fledglings was reported in British Columbia (Haug et al. 1993), although De Smet (1997) reported a return rate of only 3.5% from 538 wild-banded fledglings in Manitoba. Because we could not document any positive results from these translocations, we discontinued them.

Conclusion. Future conservation efforts for Burrowing Owls in Minnesota will depend on the status of the species and the priorities of Minnesota's Nongame Wildlife Program. Given the lack of recent breeding records and the uncertain future for this species in Minnesota, no management or research is planned beyond protection under current state and federal legislation (e.g., Migratory Bird Treaty Act, Minnesota Endangered Species Act). Should this situation change, habitat protection, management, and public education and cooperation will become important. Selective use of reintroduction may also be useful in enhancing these efforts (Martell 1990). Specific research needs include information on population demographics, migration, and winter ecology.

ACKNOWLEDGMENTS

Financial support for this work was provided by the Minnesota Department of Natural Resources Nongame Wildlife Program, the Minnesota Chapter of The Nature Conservancy, the Minnesota Agricultural Experiment Station, The Raptor Center at the University of Minnesota, and the St. Paul Audubon Society. We were assisted in the field by G. Buhl, C. Curran, E. Lawler, M. Linder, J Nibe, and L. Pohglase. Special thanks are due to D. and D. Soehren. We are especially grateful to E. Haug, L. Pfannmuller, H. Tordoff, D. Smith, and P. Redig for advice during various stages of this project. T. Wellicome, K. Hasselblad, and D. Low provided valuable comments and review.

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J Raptor Res. 35(4):337–343

A PRELIMINARY ASSESSMENT OF BURROWING OWL POPULATION STATUS IN WYOMING

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ABSTRACT.—Currently, little is known about Burrowing Owl (*Athene cunicularia*) abundance in Wyoming. The Wyoming Game and Fish Department (WGFD) classifies the Burrowing Owl as a Species of Special Concern. We identified available data sources to assess Burrowing Owl distribution and population trends in Wyoming and conducted a population survey in eastern Wyoming. The WGFD's Wildlife Observation System (WOS), initiated in 1974, shows a decline in Burrowing Owl records, particularly during the 12-yr period 1986–97. However, trends in WOS records over time likely reflect changing interest in the database, rather than real population trends. Likewise, Breeding Bird Survey data since 1971 suggest a negative trend, but low numbers warrant caution in interpreting these data. Additional monitoring efforts are required to assess Burrowing Owl population trend more accurately within the state. To evaluate Burrowing Owl abundance at historical nesting locations, we surveyed 103 previously reported sites. A total of 18% of these historical sites was reoccupied in 1999. We also surveyed 85 plots selected at random from northern mixed- and short-grass prairie types to obtain an unbiased picture of Burrowing Owl distribution in eastern Wyoming. Only one owl was found on these random survey plots, emphasizing the importance of historical nesting sites to Wyoming Burrowing Owls.

KEY WORDS: *Burrowing Owl*; Athene cunicularia; *Wildlife Observation System*; *Breeding Bird Survey*; *population trend*; *site reoccupancy*; *Wyoming*.

Evaluación preliminar del estado de las poblaciones de Búho Cavador en Wyoming

RESUMEN.—Actualmente, se sabe poco sobre la abundancia del Búho Cavador (*Athene cunicularia*) in Wyoming. El Departamento de caza y pesca de Wyoming (WGFD) clasifica al Búho Cavador como una especie de especial interés. Nosotros identificamos fuentes de datos disponibles para evaluar las tendencias poblacionales y de distribución del Búho Cavador en Wyoming y condujimos un estudio de la población en el este de Wyoming. El Sistema de Observación de Vida Silvestre (WOS) del WGFD, iniciado en 1974, muestra una reducción en los registros de Búhos Cavadores, particularmente durante el periodo 1986–97. Sin embargo, las tendencias en los registros del WOS a lo largo del tiempo probablemente reflejan intereses cambiantes en la base de datos, mas que tendencias poblacionales reales. De igual modo, los datos del Estudio de Reproducción de Aves desde 1971 sugieren una tendencia negativa, pero sus bajos números requieren de cuidado al momento de interpretar esos datos. Se necesitan esfuerzos de monitoreo adicionales para evaluar mas exactamente la tendencia poblacional del Búho Cavador dentro del estado. Para valorar la abundancia del Búho Cavador en localidades de anidación históricas, estudiamos 103 sitios previamente reportados. Un total de 18% de estos sitios históricos fueron reocupados en 1999. Además estudiamos 85 parcelas seleccionados aleatoriamente de praderas norteñas del tipo de yerbas mixtas y de hierba corta para obtener una visión sin sesgos de la distribución del Búho Cavador en el oriente de Wyoming. Unicamente un búho fue encontrado sobre esas parcelas de estudio aleatorio, enfatizando la importancia de los sitios históricos de anidación para los Búhos Cavadores en Wyoming.

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Wyoming is centrally located within the breeding range of the Burrowing Owl (*Athene cunicularia*), a species thought to be declining across much of its range in North America (James and Espie 1997). Burrowing Owls are reported to be widely distributed throughout the state in close association with black-tailed (*Cynomys ludovicianus*), and white-tailed (*C. leucurus*) prairie dog towns. Although several factors, including prairie dog eradication and habitat loss, may negatively affect the Wyoming Burrowing Owl population, little is known about population trends within the state.

Burrowing Owls are currently listed by the Wyoming Game and Fish Department (WGFD) as a Species of Special Concern, Category 4 (R. Oakleaf, A. Cerovski, R. Luce publ. comm.). This classification indicates that the species is widely distributed and suspected to be stable with no significant ongoing habitat loss. Although interest and concern for the species is growing, little work has been conducted on Burrowing Owls in Wyoming.

In light of documented declines in other portions of its range (James and Espie 1997), we evaluated available information to assess population trends and to establish baseline information for future monitoring of Burrowing Owls in Wyoming. We examined three sources of information: the Wyoming Game and Fish Department's (WGFD) Wildlife Observation System (WOS), Breeding Bird Survey data (BBS), and field data from a 1999 occupancy survey of historical and randomly-selected sites in eastern Wyoming. Each of these sources present different opportunities and limitations, and must be interpreted with discretion.

Our objective for the 1999 field survey was to establish baseline distribution and abundance data for Wyoming Burrowing Owls. We surveyed 103 historical breeding sites to determine reoccupancy of the sites. These results provide a useful baseline for future monitoring in Wyoming and allow comparisons to other states with data collection systems similar to the WOS. As such records may not represent the true distribution of Burrowing Owls in Wyoming accurately, we also surveyed 85 random sites in potential Burrowing Owl habitat to obtain an unbiased picture of distribution.

Available data were largely inadequate to address our objectives completely. Nonetheless, we believe it is important that current data be evaluated to provide a preliminary assessment of Burrowing Owl population status in Wyoming and to identify biases, information gaps, and areas for improvement in future monitoring. Therefore, we present the available data from three sources, along with cautious interpretation of trends.

METHODS

WOS Analysis. The WOS is a database comprising wildlife sightings within the state, reported voluntarily by state and federal biologists, researchers, Audubon Society members, and interested members of the general public. The WOS database is extensive, containing 713 records of Burrowing Owl sightings between 1974, when the WOS began, and 1997. We analyzed all records of adult and unknown-aged Burrowing Owl sightings made between 1 March–31 August, to exclude records of migratory birds from other populations. We sorted records by date and tallied total numbers of reports for each year. Change in numbers of records may correlate with population trend; therefore, the number of observations per year were graphed and examined for trend. Attention to Burrowing Owls increased in the late-1970s and early-1980s with the initiation of a non-game program within the WGFD (R. Oakleaf pers. comm.) and a University of Wyoming graduate research study on Burrowing Owls (Thompson 1984). Because of this probable reporting bias, we excluded early records of the WOS and performed a least-squares regression on the sightings made in the 12-yr period, 1986–97. To assess the validity of trends in the WOS records, we also examined WOS records for raptor species with suspected stable or increasing populations. We expected *a priori* that American Kestrel (*Falco sparverius*) and Red-tailed Hawk (*Buteo jamaicensis*) WOS records would remain stable with time, while WOS records for the Bald Eagle (*Haliaeetus leucocephalus*) would show an increasing trend. All regression analyses were one-tailed tests of the null hypothesis that no positive trend was present in WOS records for a species over time ($\alpha = 0.05$).

BBS Data. Wyoming BBS data are collected by annual, standardized surveys of selected roadside routes. Each observer records all bird species heard or seen within a 0.4-km radius from sample points during a 3-min period along selected survey routes. In most areas of the state, the June BBS survey coincides with the emergence of nestling owls and the presence of conspicuous adult Burrowing Owls in the vicinity of burrows.

We used the North American BBS web pages to obtain trend estimates for Wyoming populations of Burrowing Owl (Sauer et al. 1997), American Kestrel, and Red-tailed Hawk (Sauer et al. 1999). For Bald Eagles, we obtained a trend estimate for the entire Western BBS region because of an extremely small sample size when Wyoming was considered alone ($N = 3$). Estimates were calculated using route-regression trend estimation (Geissler and Sauer 1990). For Burrowing Owls, we examined two time periods: 1971–96 (the full BBS dataset) and 1986–96 (corresponding to the truncated WOS dataset). For all other raptors, we examined the time period 1980–98. We chose an $\alpha = 0.05$ to evaluate significance of trend estimates.

Because BBS data were also reported to the WOS, these two data sources were not strictly independent. However, BBS sightings constitute only a minor portion of the total WOS records. Because the WOS is probably not greatly affected by BBS data, these two data sources were considered separately.

Reoccupancy Survey. In 1999, we surveyed for Burrowing Owls in random and historical (identified from WOS records) sites east of 108° longitude. We restricted the survey to eastern Wyoming for logistical reasons and because this area contains the largest contiguous tracts of northern mixed- and short-grass prairie.

Historical sites ($N = 103$) were chosen at random from a pool of WOS records with ≥2 Burrowing Owls per sighting; historical records with multiple Burrowing Owl sightings were more likely to represent historical breeding locations as opposed to sightings of individual birds. Because some Burrowing Owl populations show high site-fidelity (Haug et al. 1993), WOS records of all ages (i.e., number of years since an original sighting) were considered. Historical sites comprised a broad array of habitat types and qualities, ranging from isolated and undisturbed to urban or cultivated lands.

We also surveyed a total of 85 random sites in eastern Wyoming. We systematically selected 55 survey sites from a pool of state sections (Section 36 in each Township, 2.6 km^2) with a dominant vegetation type of northern mixed- or short-grass prairie. Because these vegetation types represent the most likely Burrowing Owl habitat, we refer to these as "high-probability" random sites. We also selected 30 "low-probability" sites at random from a pool of state sections with dominant vegetation types of sagebrush, irrigated croplands, or desert shrub. We selected state sections (public land) to facilitate property access. In each state section, we surveyed the southeastern quarter-section (64.75 ha) using four point counts, which were then pooled to yield a total Burrowing Owl count for the quarter-section. Individual Burrowing Owls were counted only once, and only adults contributed to the count. When the selected quarter-section was not accessible, we randomly selected one of the four adjacent state sections and sampled the southeastern quarter-section.

Surveys were conducted 15 May–1 August 1999. Sites were surveyed between sunrise and 1100 H and between 1700 H and sunset (Haug and Didiuk 1993), and only when wind speeds were <20 km/hr, with no precipitation. Each quarter-section was surveyed from all four sides unless access to one side was not possible, in which case we surveyed an additional point on an adjacent quarter-section. When hills, vegetation, or other features impaired visibility, we walked or drove into the quarter-section until visibility improved.

At each station, we conducted a 12-min search using a 15× spotting scope and 10× binoculars. The search period was divided into three parts: a 5-min observation period, during which we looked and listened for owls, a 2-min Burrowing Owl call playback and search period, and another 5-min listening and search period. The use of recorded calls greatly increases the ability to detect both male and female Burrowing Owls (Haug and Didiuk 1993). We used a megaphone and a tape player to transmit a male territorial call and a "chuck-and-chatter" call. Adult owls were sexed based on coloration and behavioral differences (Martin 1973).

RESULTS

WOS Analysis. A map of all WOS record locations (Fig. 1) showed that Burrowing Owl sightings were distributed broadly throughout Wyoming, with highest concentrations occurring in the southern half of the state. Two trends were evident from the curvilinear shape of the WOS data over time (Fig. 2): numbers of records generally increased between 1974–80 to a maximum of 56 in 1981, and record numbers decreased between 1981–97. There was a significant, negative linear relationship ($P = 0.002$, $r^2 = 0.64$) between numbers of Burrowing Owl sightings and year for the 1986–97 subset of the WOS data (Fig. 2). The regressions of WOS American Kestrel ($P < 0.001$, $r^2 = 0.71$) and Red-tailed Hawk ($P < 0.001$, $r^2 = 0.83$) sightings vs. year were also negative and highly significant (Fig. 3). Bald Eagle records also decreased over time ($P = 0.002$, $r^2 = 0.63$; Fig. 3).

BBS Data. The BBS trend analysis for Burrowing Owls in Wyoming during the time period 1971–96 showed a significant trend of −37.42% ($P = 0.012$). This trend estimate was based on data from nine surveyed routes, the maximum number of routes for which a trend estimate could be obtained with Wyoming BBS data. The trend estimate for the 1986–96 time period was −33.37% ($P = 0.182$, $N = 5$ routes).

For Bald Eagles, the Western BBS region showed a trend of +3.8% ($P = 0.05$, $N = 65$ routes). The trends for Red-tailed Hawk and American Kestrel BBS sightings in Wyoming were +3.7% ($P = 0.05$, $N = 75$) and +2.5% ($P = 0.23$, $N = 81$), respectively.

Reoccupancy Survey. Burrowing Owl sightings were distributed throughout eastern Wyoming, with higher concentrations occurring around Buffalo, Torrington, and Rawlins (Fig. 1). Of 188 sites surveyed, a total of 37 owls were seen at 16 sites. Thirty-six of the detected owls were located on WOS historical sites ($N = 103$), one Burrowing Owl was found on a random high-probability site ($N = 55$), and none was detected on random low-probability sites ($N = 30$). Of the 103 historical sites that were revisited, 17.5% were reoccupied in 1999.

A total of 43% of occupied sites ($N = 16$) and 10% of unoccupied sites ($N = 168$) were also currently occupied by black- or white-tailed prairie dogs. A logistic regression showed the presence of Burrowing Owls was a positive function of the pres-

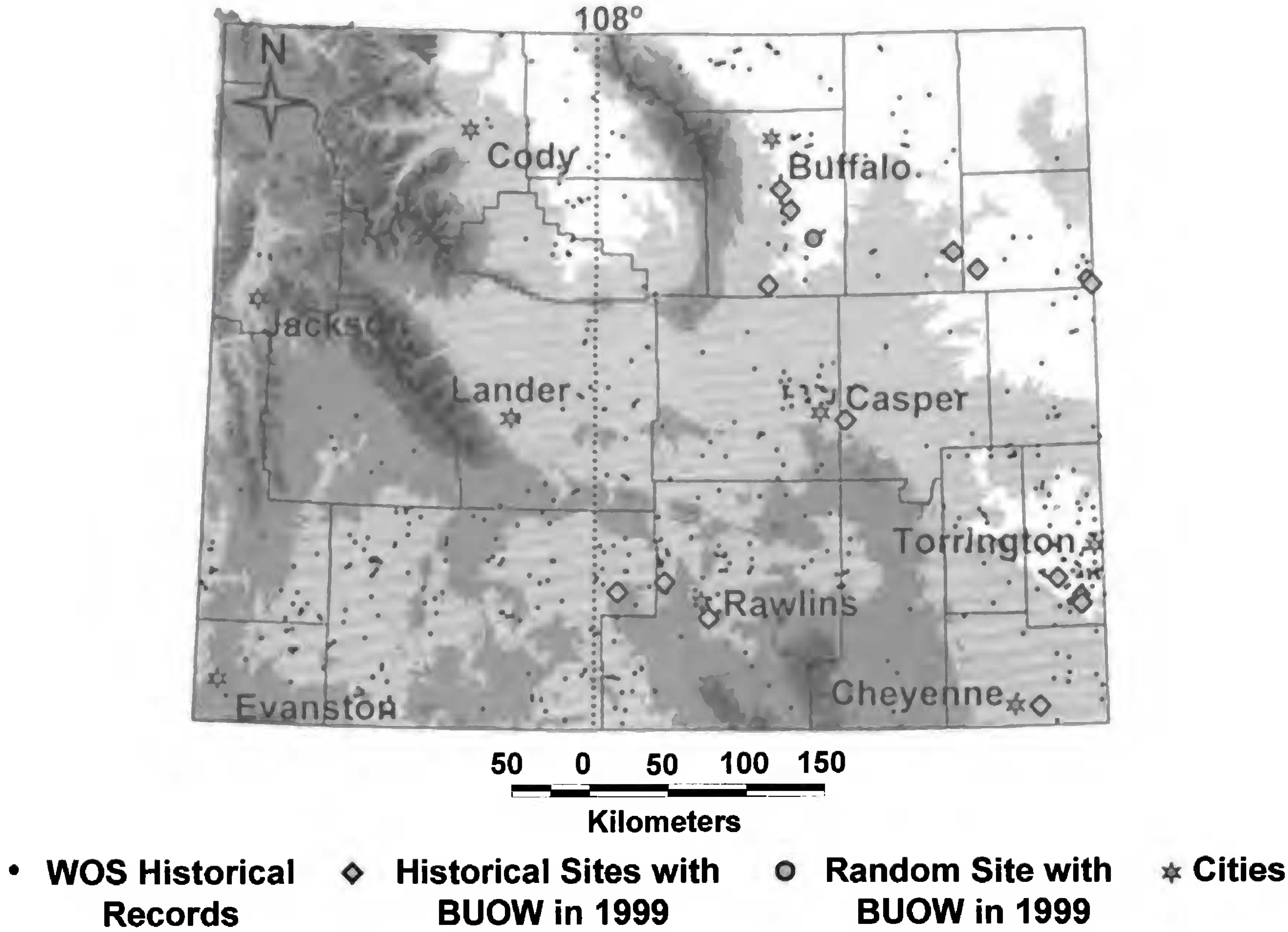

Figure 1. Wildlife Observation System (WOS) historical records and 1999 reoccupancy survey sites with Burrowing Owls (BUOW).

ence of prairie dogs ($B = 1.92$, df = 1, $P = 0.001$). Burrowing Owls not found in association with active prairie dog colonies generally nested in inactive prairie dog towns or burrows excavated by badgers (*Taxidea taxus*), Wyoming ground squirrels (*Spermophilus elegans elegans*), thirteen-lined ground squirrels (*S. tridecemlineatus*), or red foxes (*Vulpes vulpes*). A total of 19% of the occupied sites, and 23% of unoccupied sites were currently or recently (within the previous year) grazed by cattle, sheep, or buffalo (*Bison bison*). There was no significant difference between these values ($P = 0.679$).

DISCUSSION

We examined three data sources, including BBS, WOS, and 1999 reoccupancy survey data, to evaluate the quality of available data and to determine trend in Burrowing Owl relative abundance in Wyoming. None of these data sources alone was sufficient to define Burrowing Owl population status. Our analyses indicated that existing data sources were inadequate to evaluate trends in the Wyoming Burrowing Owl population.

The WOS documents a large number of Burrowing Owl sightings over a relatively long time period; however, it is limited by two major reporting biases. First, search effort is not consistent among years, making the number of records in the database contingent on interest in the species and interest in the database. Because the WOS does not include information on search effort, population trends are inextricable from changing interest in a species. This was demonstrated by declines in American Kestrel, Red-tailed Hawk, and Bald Eagle records during 1986–97. BBS data for a similar time period suggest that populations of all three of these species are stable or increasing in Wyoming. WOS declines are likely accounted for by decreased reporting of sightings to the database by researchers and birders rather than by declines in actual abundance of the species. Thus, although Burrowing Owl WOS records have declined signif-

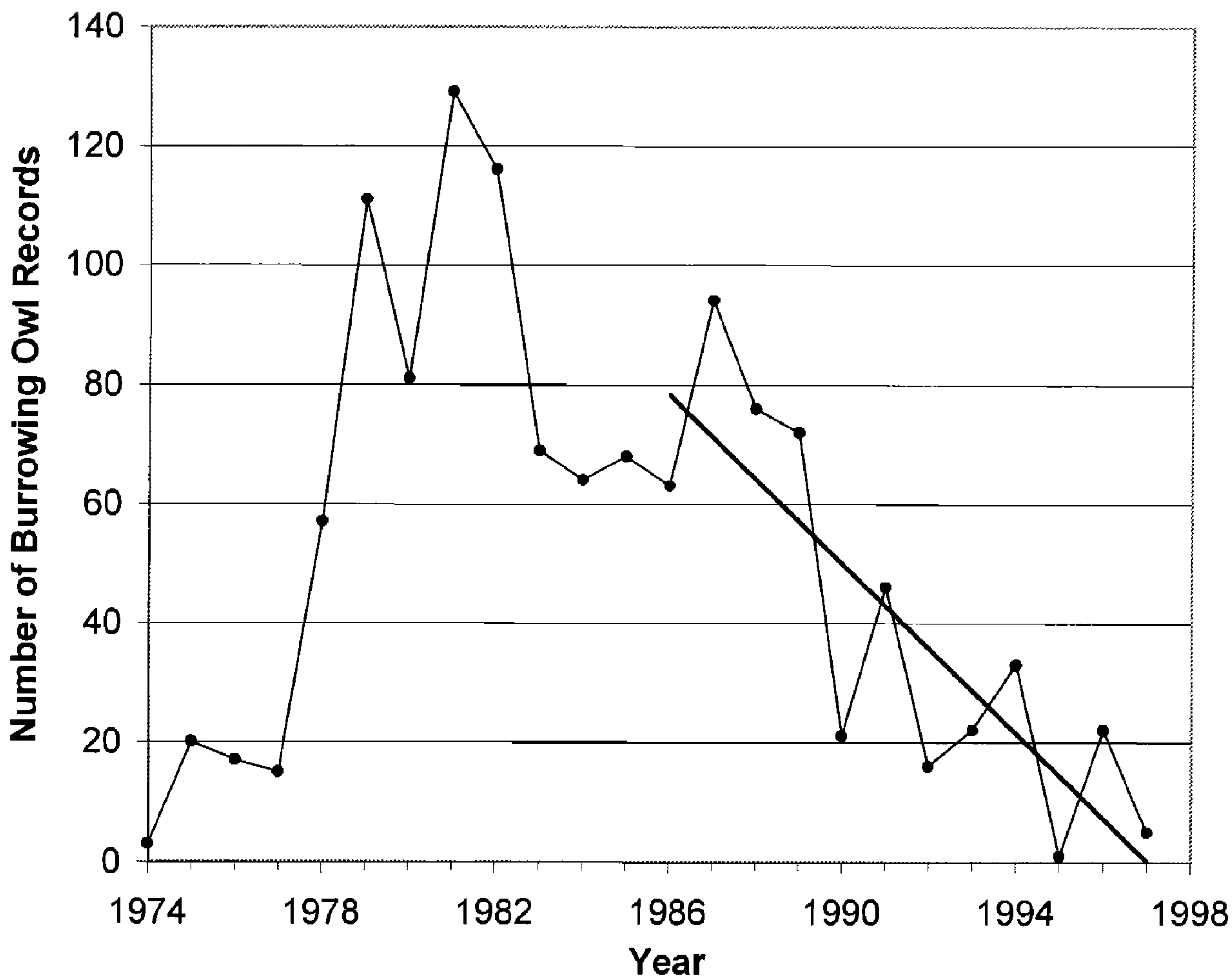

Figure 2. Numbers of Burrowing Owl records per year in the Wyoming Game and Fish Department's Wildlife Observation System (WOS). The significant decline in Burrowing Owl records during the period 1986–97 may represent either declining Burrowing Owl abundance or decreasing interest in the WOS database.

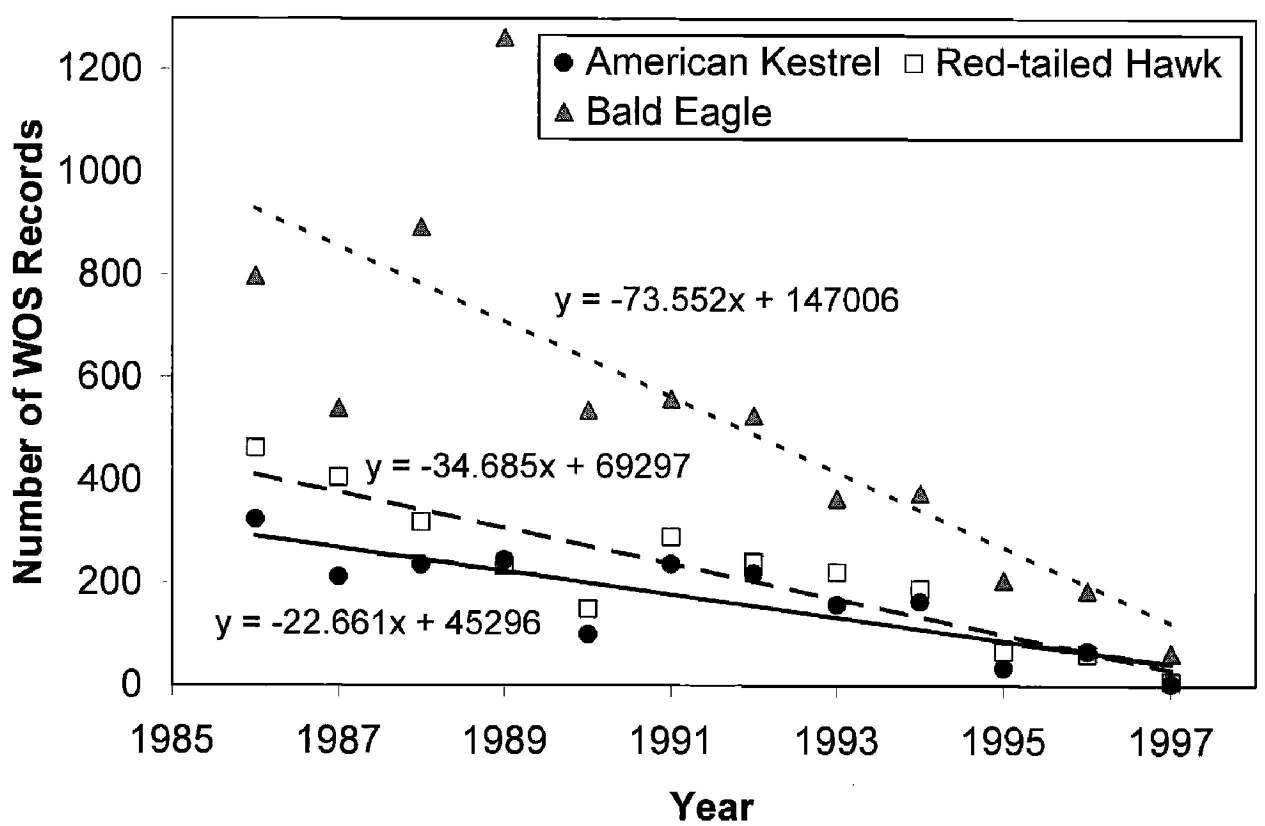

Figure 3. Trends in Wyoming Game and Fish Department's Wildlife Observation System (WOS) records over time for raptors identified by the Breeding Bird Survey as stable (American Kestrel and Red-tailed Hawk) or increasing (Bald Eagle).

icantly in recent years, it is impossible to know to what extent this decline reflects the actual population trend. In addition to this temporal bias, the WOS may also be spatially biased. Burrowing Owl colonies closer to urban areas or roads are probably better represented in the WOS than are more remote colonies, which are less likely to be detected by biologists and birders. This bias may affect the distribution information. For instance, clusters of Burrowing Owl records near towns may be either a function of easier human access or the preferred use of semi-urban landscapes by Burrowing Owls, a behavior that has been documented in other populations (Haug et al. 1993). Although the WOS may be valuable in identifying historical nesting locations, it may not afford a representative view of Burrowing Owl distribution in the state.

Although the BBS has the advantage of standardized sampling effort and is not subject to reporting biases characteristic of the WOS, these data must be carefully interpreted. In all time periods considered, few routes documented Burrowing Owls in Wyoming. A minimum of 14 routes are necessary for reliable trend estimates (J.R. Sauer publ. comm.); hence, the small sample size in Wyoming makes the accuracy of trend estimates questionable. In addition, the survey approach used in the BBS is best suited for common or high-density species. Burrowing Owls are often spatially clustered because of their association with prairie dog towns (Desmond et al. 1995), so a BBS route that intersects a prairie dog town may result in several Burrowing Owl sightings. If a given route does not pass near a town, it is unlikely that any Burrowing Owls will be sighted. Because of the specialized habitat and the low relative abundance of this species, variance among routes and among years is high, resulting in imprecise trend estimates. Despite this potential for imprecision, trend estimates were significantly negative for routes with Burrowing Owls.

Surveying historical nesting locations could be a valuable means of detecting trends in Burrowing Owl populations at historical nesting areas if it is repeated in the future. While reoccupancy seems quite low, we currently have no quantitative means to assess the significance of a 17.5% reoccupancy of historical sites. Survey of historical sites alone may artificially result in a low reoccupancy simply because of the slow movement of prairie dog towns and Burrowing Owl aggregations through time away from initial, historical nesting locations (Rich 1984). For this reason, and to assess Burrowing Owl distribution in an objective manner, we also surveyed random sites. We found only one Burrowing Owl on 85 random sites; thus, it appeared that vegetation type alone was an insufficient site-selection criterion. Future surveys could use vegetation parameters in conjunction with prairie dog town locations to identify potential Burrowing Owl habitat more precisely for survey. The paucity of Burrowing Owl detections on random survey sites also suggests that conservation of established nesting locations is important.

In areas where Burrowing Owls are sympatric with prairie dogs, the owls are thought to prefer nesting in active prairie dog towns because of improved predator detection (e.g., Haug et al. 1993, Desmond et al. 1995). However, our results show that fewer than half of the detected Burrowing Owl nests were associated with active prairie dog towns. Two possibilities exist to explain the lack of Burrowing Owl and prairie dog co-occurrence in eastern Wyoming: 1) association with prairie dogs may not confer advantages such as increased predator detection or, 2) although nonprairie dog habitat is suboptimal, site fidelity may keep the owls in areas of declining quality. Heavy reliance on mammals other than prairie dogs for burrow excavation has not been previously documented for Burrowing Owl populations co-occurring with prairie dogs, although this does occur elsewhere within the Burrowing Owl's range (Haug et al. 1993). Additional research is needed to confirm the prevalence of this nesting strategy and to determine its effect on population dynamics and persistence.

Existing databases are incapable of detecting more than gross trends for the Wyoming Burrowing Owl population. Both the WOS and BBS indicated significant declines in Burrowing Owl abundance; however, reporting bias and sample sizes hindered inference from either source. The statewide reoccupancy study at historical sites must be repeated before we can assess its capacity for documenting population trend. Thus, we recommend that a regular standardized survey be implemented, which incorporates and expands upon our preliminary efforts.

In spite of its associated biases, the WOS provides a useful resource to identify broad-scale distribution patterns and historical nesting locations in the state. Given high site-fidelity of the species documented in other studies (Haug et al. 1993) and the results of our reoccupancy study, it appears that management of these historical nesting sites would have the greatest conservation impact for Burrowing Owls in Wyoming.

ACKNOWLEDGEMENTS

Thanks to Brady Morris for his large contribution to the Burrowing Owl field surveys. Thanks also to Drs. Gregory Hayward, Troy Wellicome, and Geoffrey Holroyd, and two anonymous reviewers for providing suggestions that improved the manuscript significantly. Robert Oakleaf (WGFD) served as an excellent source of information on the WOS. Funding for this study was provided by The Wyoming Nature Conservancy, The Nature Conservancy's Wings of the Americas program, Wyoming Game and Fish Department, Biological Resource Division of the USGS, and the University of Wyoming College of Arts and Sciences. Thanks to Drs. Jerry Freilich and Charles Duncan of The Nature Conservancy for providing funding opportunities and other essential assistance. This project would not have been possible without the many Wyoming landowners who graciously allowed us access.

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THE HOWDY OWLS OF ARIZONA: A REVIEW OF THE STATUS OF *ATHENE CUNICULARIA*

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ABSTRACT.—Available information on the status of the western Burrowing Owl (*Athene cunicularia hypugaea*) in Arizona is limited. To determine its current status, I sent out questionnaires, made personal contacts, conducted field observations, and searched the literature. These data indicated that relatively little is known in Arizona about this uncommon species. This paper summarizes existing information on the Burrowing Owl in Arizona and provides baseline information for future studies. Location records suggest that this species is a widespread, albeit uncommon, bird in Arizona. The data compiled during this study are still not adequate to assess the status of Burrowing Owls in Arizona as of 1998. An annotated bibliography of Burrowing Owls in Arizona is available upon request.

KEY WORDS: *Burrowing Owl;* Athene cunicularia; *Gunnison's prairie dog;* Cynomys gunnisoni; *round-tailed ground squirrel;* Spermophilus tereticaudus; *distribution; status review; Arizona.*

Los Búhos Cavadores de Arizona: una revisión del estado de *Athene cunicularia*

RESUMEN.—La información disponible sobre el estado del Búho Cavador occidental (*Athene cunicularia hypugaea*) en Arizona es limitada. Para determinar su estado actual, envié cuestionarios haciendo contactos personales, conduje observaciones de campo, e investigue en la literatura. Este articulo resume la información existente sobre el Búho Cavador en Arizona y provee de información básica para futuros estudios. Las localidades registradas sugieren que esta especie es de amplia distribución, a pesar de ser un ave poco común en Arizona. Los datos compilados durante este estudio son aun inadecuados para evaluar el estado del Búho Cavador in Arizona para 1998. La bibliografía comentada sobre el Búho Cavador en Arizona esta disponible por encargo.

[Traducción de Victor Vanegas y César Márquez]

The Western Burrowing Owl (*Athene cunicularia hypugaea*), also known as the howdy owl, is considered to be a generally uncommon, local resident in a variety of habitats within Arizona (Phillips et al. 1964, Monson and Phillips 1981). One exception is in the agricultural lands near Yuma, where they are considered to be common (Monson and Phillips 1981, Rosenberg et al. 1991). Relative to other areas within its range in Canada and the United States of America, not much is known about this species in Arizona. The status of the Burrowing Owl in this state was reviewed in 1979 (Johnson et al. 1979) and again in 1986 (Johnson-Duncan et al. 1988), but results were incomplete. Provided, herein, is a summary of data on Burrowing Owls in Arizona, including distribution, habitat types, and threats to the species.

METHODS

In April 1998, I sent out over 100 questionnaires regarding Burrowing Owls to various federal and state land management and resources agencies, independent biologists, and bird enthusiasts throughout the state. The questionnaire asked for the following information: 1) Are Burrowing Owls known to occur on your property or in your region? 2) Can you provide any locations of Burrowing Owls? 3) Can you determine if the owl population in your area is stable, increasing, or decreasing, and if decreasing then why? and 4) Can you identify any known or potential threats to the owls in your area? Approximately 50% of the questionnaires were completed and returned. I also requested observations from an Arizona/New Mexico rare-bird website (*http://naturesongs.com/birdyverde*). In addition, the Arizona Game and Fish Department provided Arizona Breeding Bird Atlas (ABBA) data from 1993–99. Lastly, I conducted literature searches and field observations, and produced an annotated bibliography and a database containing over 280 general and specific records related to Burrowing Owls in Arizona.

RESULTS AND DISCUSSION

Distribution and Migratory Status. In Arizona, Burrowing Owls are found in a variety of open hab-

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itats that are scattered throughout the state (Fig. 1). There are observations of this species in all but two of the 15 counties (no records from Greenlee County). Of the 13 counties with records, Santa Cruz County lacks a confirmed breeding record.

The migratory habits of Burrowing Owls in Arizona are not well-understood (Phillips et al. 1964, deVos 1998). The populations in northern Arizona are thought to migrate out of the area for the winter months (Woodbury and Russell 1945, Phillips 1947, Phillips et al. 1964, Monson and Phillips 1981, Jacobs 1986, J. Coons, C. LaRue, B. VanPelt pers. comm.). Some authors have referred to the owls as permanent residents in the Flagstaff area (Carothers et al. 1970, 1973) and in the Oraibi Valley on the Hopi Reservation (Bradfield 1974). However, Bradfield's (1974) information was passed secondhand and was not substantiated by direct observation. At present, there are only two winter records from northern Arizona: Snowflake, 22 December 1947, and Springerville, 8 January 1959 (Phillips et al. 1964, Monson and Phillips 1981). According to Tyler and Phillips (1978), these owls are resident everywhere in Arizona except in the northeast. DeVos (1998) suggested that Burrowing Owls in Arizona occur locally in open areas, generally year-round, even in the northeastern part of the state. DeVos (1998) apparently based this suggestion on Bradfield's records, because there were no survey data on this species at that time (R. Glinski pers. comm.). In the northeastern portion of the state, existing records suggest the owls arrive on the breeding grounds around mid-March and migrate out of the area by mid-October (Jacobs 1986, C. LaRue pers. comm.).

The mild winter climate along the Lower Colorado River may provide year-round habitat for this species. Phillips et al. (1964) reported summer, winter, and transient records along the Lower Colorado River Valley. Rosenberg et al. (1991) considered the owls a common resident throughout the Lower Colorado Valley, but less common in the northern region of the valley in winter.

Phillips et al. (1964) contended that the owls from around the Phoenix area (central Arizona) and in southern Arizona (south of Phoenix) were year-round residents. However, Rhea (1983) believed that some of the owls along the Gila River, south of Phoenix, were migratory; in 13 yr, he had seen only two pairs of owls during the winter. Monson and Phillips (1981) suggested that some of the owls in the area east of the San Pedro Valley, in the southeastern region, also migrate in the winter. Zarn (1974) implied that in the winter there is a tendency for resident owls to wander extensively or become strictly nocturnal. Whether the absence of owls from their known burrows in these parts of Arizona was due to migration, wandering, or lack of diurnal activity is unknown.

Habitat. The Western Burrowing Owl typically relies on other fossorial animals to create its burrows (Brandt 1951, Evans 1982, Thomsen 1971, Zarn 1974, Haug et al. 1993). Thus, the presence of a nest burrow seems to be a critical habitat requirement for this species in the western states (Haug et al. 1993); however, the presence of a nest burrow is only one factor that makes an area suitable. Zarn (1974) lists three factors necessary for good Burrowing Owl habitat: 1) openness, 2) short vegetation, and 3) burrow availability. Some fossorial mammals, such as Gunnison's prairie dogs (*Cynomys gunnisoni*) and round-tailed ground squirrels (*Spermophilus tereticaudus*), inhabit open environments, provide burrows and help maintain short vegetation by foraging (Butts 1973, Hoffmeister 1986, deVos 1998).

In the western portion of its range, Burrowing Owls are often associated with mammal burrows in open, dry grasslands, agricultural and range lands, and desert habitats (Haug et al. 1993, deVos 1998, ABBA unpubl. data, N. Brown unpubl. data). Burrowing Owls also inhabit grass, forb, and open shrub stages of pinyon pine (*Pinus edulis*) and ponderosa pine (*Pinus ponderosa*) habitats (Carothers et al. 1973, Karlaus and Eckert 1974, State of California 1990). Other areas in Arizona where owls might be found include natural drainage systems, irrigation canals, near water tanks or corrals on rangelands, and in vacant lots, parks, airports, golf courses, cemeteries, and other disturbed sites in urban and rural areas (Rhea 1983, Rosenberg et al. 1991, Witzeman et al. 1997, deVos 1998, N. Brown unpubl. data). Occasionally owls are found in sandy, sparsely vegetated riparian woodlands in the Lower Colorado River Valley (Rosenberg et al. 1991).

The ABBA surveys (Arizona Game and Fish Dept., Phoenix) recorded them in the following vegetation types: Semidesert Grassland, Plains Grassland, Cropland, Great Basin Desertscrub, Lower Colorado River Biome of Sonoran Desertscrub, Barren ground, Great Basin Grassland, Arizona Upland Biome of Sonoran Desertscrub, Mo-

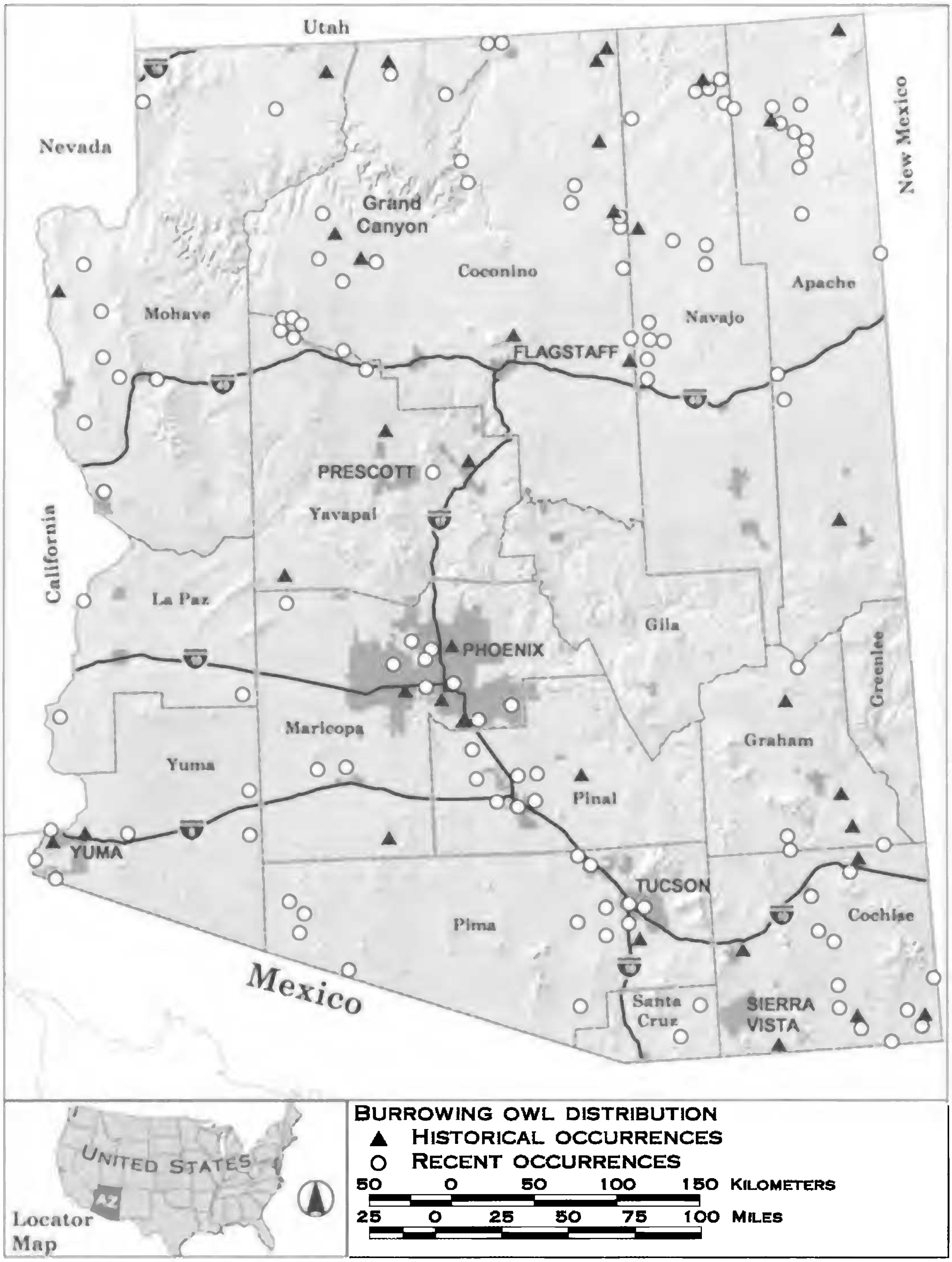

Figure 1. Historical and recent occurrences of Burrowing Owls in Arizona.

jave Desertscrub, Rural (includes canals and pastures), and Residential. From the 1998 survey data, parks, including golf courses and cemeteries, and cultivated woodlands, including orchards and tree farms, may be added to this list.

Carothers et al. (1973) reported the first record of a Burrowing Owl in Flagstaff in ponderosa pine vegetation type on 2 April 1970; P. Snider (pers. comm.) provided a second record from 12 May 1974 on the Northern Arizona University campus, Flagstaff. Because these are the only two records for Flagstaff, these owls may have either wandered in from the grasslands northeast of Flagstaff, where a population was reported (Carothers et al. 1973), or were transients in Flagstaff while on migration.

Much of the natural habitat for Burrowing Owls is on either private or inaccessible lands. Inaccessible lands include closed-to-public government lands and tribal or nation lands. The latter, estimated to be ca. 8 million ha in Arizona (World Almanac Books 1998), are only accessible via major roadways or by daily permits in selected areas.

Nesting. Burrowing Owls nest in holes, burrows, or similar underground structures. In Arizona, animals that excavate burrows include Gunnison's prairie dog, round-tailed ground squirrels, rock squirrels (*Spermophilus variegatus*), California ground squirrels (*Spermophilus beecheyi),* pocket gophers (*Thomomys* spp.), kangaroo rats (*Dipodomys* spp.) (particularly the larger banner-tailed [*D. spectabilis*] and desert [*D. deserti*]), coyotes (*Canis latrans*), kit fox (*Vulpes macrotis*), gray fox (*Urocyon cinereoargenteus*), red fox (*Vulpes vulpes*), skunks (*Mephitis, Spilogale,* and *Conepatus* spp.), badgers (*Taxidea taxus*), and desert tortoise (*Gopherus agassizii*) (Merriam 1890, Visher 1910, Swarth 1914, Phillips et al. 1964, Haug et al. 1993, N. Brown unpubl. data). Prior to their extirpation, black-tailed prairie dogs (*Cynomys ludovicianus*) provided burrows in southeastern Arizona (Osgood 1903, Swarth 1904, 1914, Brandt 1951, Phillips et al. 1964). The owls are known to utilize a variety of man-made structures, such as drain and irrigation pipes and culverts, artificial landscapes (waterfalls), and artificial burrows (Haug et al. 1993, N. Brown unpubl. data). Woodbury and Russell (1945) suggested that the owl burrows they found near Cow Springs were dug by the owls themselves and not by prairie dogs. There is also one record of a pair utilizing a cavity "well off the ground" in a paloverde (*Cercidium* sp.) in the Phoenix area (B. Millsap pers. comm.).

In Arizona, records suggest that the nesting season begins between mid-March and April (Phillips et al. 1964, N. Brown, T. Estabrook, and R. Mannan unpubl. data). The owls often decorate the outside of their burrow and line their nest with an assortment of materials, such as prey remains, pellets, feathers, cow and horse manure, coyote scat, parts of cacti, and artificial materials (Brandt 1951, Zarn 1974, N. Brown pers. observ.).

Changes in Abundance Over Time. Monson and Phillips (1981) considered Burrowing Owls to be locally common near farmlands around Phoenix. However, Witzeman et al. (1997) reported that they were increasingly difficult to find. The three locations where owls can be seen reliably are Scottsdale Community College, Painted Rock Dam, and Chandler Airport (Witzeman et al. 1997, N. Brown unpubl. data).

Monson and Phillips (1981) reported that the February 1949 observation of a Burrowing Owl in north Growler Valley in southwestern Arizona (Sonoran Desertscrub vegetation) was unusual. G. Monson (pers. comm.) stated he had no owls in this area from 1954–62. However, in early 1994, Burrowing Owls were seen and heard in the Growler Valley on the Cabeza Prieta National Wildlife Refuge, and in 1995, nesting was confirmed (T. Cutler and D. Griffith pers. comm.). No year-round surveys have been conducted in this region.

In the Grand Canyon region, Bailey (1939) reported a few records, but the last sighting was in 1937, soon after intensive prairie dog control programs. Burrowing Owls were formerly found near Anita and Pasture washes (Brown et al. 1984), but the vegetation in these areas has changed to dense brush and is presently considered to be unsuitable for this owl (L. Stevens pers. comm.). Brown et al. (1984) suggested that owls may have occurred in other open areas on the north and south rim. Bailey (1939) and Brown et al. (1984) reported no records from along the river bottom of the Grand Canyon, only from the rim. National Park Service (publ. comm. 1937) reported a September observation, from the bottom of the canyon, that was contributed by R. Grater, who had provided many of Bailey's records.

As previously mentioned, prior to 1930s, Burrowing Owls were associated with black-tailed prairie dogs and were somewhat common in southeastern Arizona (Scott 1886, Osgood 1903, Swarth 1904, 1914, Brandt 1951, Hoffmeister 1986, Phillips et al. 1964). After the extirpation of these prairie dogs by the 1950s, Brandt (1951) suggested that the Burrowing Owl was a rare species in the area. The ABBA data suggest that at least a few pairs are breeding presently in the area, and that recent grazing and grassland management practices in southeastern Arizona may benefit the owls, and the fossorial species that create their burrows.

Burrowing Owls were not found along the Lower Colorado River in the early 1900s, but now they are considered common, suggesting that agriculture (particularly irrigated crops) has benefited them (Rosenberg et al. 1991). This also seems to be the case in California where 71% of the state's population is found in the agricultural land of the Imperial Valley (D. DeSante, E. Ruhlen, and D. Rosenberg unpubl. data).

Threats. Relatively heavily-grazed areas may benefit Burrowing Owls by keeping vegetation short (Kochert et al. 1988). However, overgrazing can potentially lead to a reduction in prey, destruction of burrows, and ultimately to a change in habitat type (Brandt 1951). Also, any agricultural practice, insect, rodent, or predator control programs may adversely affect the owls through habitat change, reduction in prey, increases in predation, and potentially accidental and secondary poisoning (Brandt 1951, Zarn 1974, Marti and Marks 1989).

Burrows are sometimes destroyed when vegetation is cleared or controlled during canal and road maintenance or agricultural and construction activities (Zarn 1974, T. Estabrook and R. Mannan unpubl. data). Some of these activities could be restricted to outside of the Burrowing Owl's breeding season, thus limiting disturbance during this critical period.

Conversion of lands for urbanization or agricultural purposes destroys natural habitat, but may potentially create temporary habitat for Burrowing Owls. Marti and Marks (1989) and deVos (1998) mentioned that newly created or disturbed habitats, modified by urbanization and agriculture, are important but unreliable and temporary habitats. Areas may remain undeveloped for a period of time, long enough for ground squirrels to create burrows that Burrowing Owls can also use; however, the land is eventually developed. Urbanization results in more interactions with humans (collisions with vehicles and windows, harassment and predation by children and pets). Also, urbanization may increase the chances of Trichomoniasis, a disease acquired from doves (T. Estabrook and R. Mannan unpubl. data). Thus, these habitats cannot be considered a basis for stable populations.

Status. The Burrowing Owl is on the U.S. Fish and Wildlife Service's list of Species of Management Concern (USFWS 1995) and is federally protected by the 1972 United States-Mexico Migratory Bird Treaty Act. Burrowing Owls have no special listing by the state of Arizona. However, in October 1998, the Arizona Partners in Flight Program, coordinated by the Arizona Game and Fish Department, designated the Burrowing Owl as a Priority Species in High Elevation Grassland communities (N. Brown publ. comm.).

The status of bird species in southwestern United States has been assessed in the past (Johnson et al. 1979, Johnson-Duncan et al. 1988). However, there has never been enough information available to determine the status of the Burrowing Owl in the southwest. As of 1998, the species' status in Arizona is still unclear. The information presented in this paper is the most comprehensive currently available for Burrowing Owls in the state of Arizona.

Recommendations for Future Work.

(1) Conduct state-wide, year-round field surveys to improve knowledge of Burrowing Owl abundance and distribution.
(2) Study migratory habits of owls in Arizona by initiating telemetry and banding studies at known nest sites and monitoring during winter. If certain populations are migratory, determine habitat needs for both breeding and wintering areas.
(3) Study the owls in their natural habitats to learn more about their behavior, habitat requirements, and association with prairie dogs and other fossorial animals. Some of this research could compliment research on black-footed ferrets (*Mustela nigripes*), involve monitoring of prairie dog towns for plague, and be a component of a multi-species approach to grassland management.
(4) Develop outreach programs to educate the general public on this species. Programs could be designed to educate children in urban environments, so that they may reduce harassment of the owls, and to educate and to provide recommendations to private and public land managers regarding canal maintenance and pest control programs. The results of this review suggest that educational material on

this species for the managers of the canals and the farmers may be needed to reduce the impacts from canal maintenance. Canal maintenance that can impact this owl includes both the clearing of unwanted vegetation, which destroys burrows, and the outright destruction of burrows during erosion control and because burrow systems along the canals weaken the berms. D. DeSante, E. Ruhlen, and D. Rosenberg (unpubl. data) estimated that 92% of the Burrowing Owls in the Imperial Valley nest within 15 m of the banks of the many irrigation canals in this intensively agricultural region, and the same may be true for some of the Arizona populations inhabiting similar areas. Thus, an outreach program addressing these concerns could benefit both the Arizona and California populations.

CONCLUSION

In Arizona, the Burrowing Owl has been, and still may be, threatened by prairie dog and ground squirrel control programs, vegetation control programs, plague (indirectly), conversion of natural habitat, canal maintenance, agricultural pesticides, and overgrazing of rangelands (Brandt 1951, Phillips et al. 1964, Marti and Marks 1989, Haug et al. 1993, deVos 1998; N. Brown, T. Estabrook, and R. Mannan unpubl. data). The importance of Arizona's native grasslands to the conservation of Burrowing Owls was emphasized by deVos (1998), but we need to learn more about the owl's behavior in its natural habitat to better manage for that habitat.

ACKNOWLEDGMENTS

This was a volunteer project that would not have gotten far without the assistance and cooperation of everyone who provided information, support, and suggestions, all of which were greatly appreciated. I extend additional appreciation to the following people: R. Ditch for providing a significant amount of information; Arizona Game and Fish for their ABBA and urban data; G. Monson for all of his records and insight; S. Phillips for the map; B. Gomes for his support, time, and patience; C. LaRue, R. Radd, and the Museum of Northern Arizona (MNA) librarians for their assistance; T. Wellicome, C. Finley, R. Glinski, and R. Mesta for their suggestions and comments; and, of course, G. Holroyd for giving me the 'go-ahead' to initiate this project.

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J Raptor Res. 35(4):351–356

CURRENT STATUS, DISTRIBUTION, AND CONSERVATION OF THE BURROWING OWL IN OKLAHOMA

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Abstract.—In Oklahoma, the Burrowing Owl (*Athene cunicularia*) historically inhabited much of the western half of the state. Over the last century, habitat destruction and alteration, including destruction of prairie dog (*Cynomys* spp.) colonies, have taken a toll on the remaining Burrowing Owls in Oklahoma. Currently, owls occupy only a relatively small portion of their historical range in the state. A recent survey indicated that total colony area in the state continues to decline, decreasing 4–7% over the past 10 yr. As prairie dogs continue to be eradicated by humans and impacted by plague over significant areas of Oklahoma, it is not surprising that Burrowing Owls continue to decline. Currently, there are an estimated 800–1000 Burrowing Owls breeding in Oklahoma, and most of these occur in the three panhandle counties (Cimarron, Texas, and Beaver). Breeding Bird Survey data showed that the Burrowing Owl population has significantly declined (12.3%/yr) in the state. Christmas Bird Count data, although limited, also suggest decreasing numbers of wintering Burrowing Owls in the state. These findings are a cause of great concern for the Burrowing Owl in Oklahoma. Major cooperative efforts are needed to ensure that viable populations of Burrowing Owls continue to exist throughout the species' range in Oklahoma.

Key Words: *Burrowing Owl;* Athene cunicularia; *status; distribution; conservation; black-tailed prairie dog;* Cynomys ludovicianus; *Oklahoma.*

Estado actual, distribución, y conservación del Búho Cavador en Oklahoma

Resumen.—En Oklahoma, el Búho Cavador (*Athene cunicularia*) históricamente ha habitado la mayor parte del lado oeste del estado. En el ultimo siglo, la destrucción del hábitat y su alteración, incluyendo la destrucción de las colonias de perros de la pradera (*Cynomys* spp.) ha tomado un numero de bajas en los restantes Búhos Cavadores de Oklahoma. Actualmente los búhos ocupan solamente una porción relativamente pequeña de su rango histórico en el estado. Un estudio reciente indicó que el área total de las colonias de los perros de la pradera continua disminuyendo abruptamente, decreciendo 4–7% en los últimos 10 años. Como los perros de las praderas están siendo erradicados por los humanos y devastados por la peste sobre áreas significativas de Oklahoma, no es sorprendente que el numero de Búhos Cavadores continúe decayendo. En la actualidad, hay un estimado de 800–1000 Búhos Cavadores reproduciéndose en Oklahoma, y la mayoría de estas ocurren en los tres condados de la región "manija" (Cimarron, Texas, y Beaver). Los datos del Estudio de Aves en Reproducción muestran que las poblaciones de búho cavador han decrecido significativamente (12.3%/año) en el estado. La continuación de estas tendencias resultará probablemente en la necesidad de protección legal bajo la ley estatal de especies en peligro. Se necesitan esfuerzos cooperativos mas grandes para asegurar que poblaciones viables de Búhos Cavadores continúen existiendo a lo largo y ancho de su rango en Oklahoma.

[Traducción de Victor Vanegas y César Márquez]

Historically, the Burrowing Owl (*Athene cunicularia*) inhabited the western one-half of Oklahoma (Baumgartner and Baumgartner 1992, Haug et al. 1993). Prior to settlement of the Oklahoma Territory in the 1880s, Burrowing Owls were locally common summer residents in grasslands of central and western Oklahoma, but they were largely ex-

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tirpated by 1930 (Baumgartner and Baumgartner 1992). They were commonly found in shortgrass prairie habitats and were closely associated with black-tailed prairie dogs (*Cynomys ludovicianus*). Currently, they are a rare and local summer resident, mainly in the Oklahoma panhandle and other western counties (Baumgartner and Baumgartner 1992). Modern development and agriculture have resulted in large-scale destruction and alteration of Burrowing Owl habitat in Oklahoma and other Great Plains states. In addition, sylvatic plague (*Yersinia pestis*), shooting, and poisoning have greatly reduced prairie dog populations, resulting in population numbers that are only a fraction of what they were historically. Burrowing Owls today occupy only a relatively small portion of their historical range in Oklahoma, and numbers are greatly reduced from historical estimates. The largest populations are found in Cimarron County in the panhandle (Baumgartner and Baumgartner 1992). Currently, the Burrowing Owl is classified as a Species of Special Concern in Oklahoma (Oklahoma Department of Wildlife Conservation publ. comm.). It is also a Species of Special Concern in the neighboring state of Kansas, but has no official listing in either Texas or New Mexico (Sheffield 1997a). The black-tailed prairie dog, a species that is ecologically linked to the Burrowing Owl in the Great Plains, is also classified as a Species of Special Concern in Oklahoma (Oklahoma Department of Wildlife Conservation publ. comm.).

To date, there has been no systematic survey of Burrowing Owls in Oklahoma. In the summer of 1970, Butts (1971) studied the ecology of Burrowing Owls in Beaver and eastern Texas counties. This is the most complete estimate of population density of Burrowing Owls in Oklahoma, and there has not been a similar survey since. In 1970, the total area covered by prairie dog colonies in Oklahoma was less than half of the area it was in 1960 (Butts 1971). Burrowing Owl populations are small or nonexistent in areas of central and western Oklahoma where prairie dogs have been eradicated (Butts and Lewis 1982). The Oklahoma panhandle is still largely undeveloped, and is characterized mainly by cattle ranching, agriculture, and open prairie. In this area, prairie dog colonies are still relatively large and numerous. As you move east from the panhandle, development is more prevalent, prairie dog colonies are less frequent and more fragmented, and there are fewer Burrowing Owls (Tyler 1968, Butts and Lewis 1982, J. Shackford, J. Tyler, and L. Choate unpubl. data).

SUMMER RECORDS

The current summer (breeding) range of the Burrowing Owl in Oklahoma was derived from BBS data (1966–99), other breeding records, and personal observations. Burrowing Owl family groups have been documented during the summer months in the prairie dog colonies of 13 western counties (Fig. 1). It is likely that Burrowing Owls also nest in or around several prairie dog colonies in Cotton and Custer counties, but there are no confirmed records or sightings. Based on Tyler's (1968) data and our subjective assessment of changes since that survey, we estimated that there is a current summer population of 800–1000 Burrowing Owls in Oklahoma, with most owls occurring in the three panhandle counties (Cimarron, Texas, and Beaver; Fig. 1).

Tyler (1968) surveyed black-tailed prairie dog colonies in Oklahoma, recording a total of 788 Burrowing Owls, and derived a state population estimate of 900–1000 individuals. In his survey in 1970, Butts (1971) found a total of 543 Burrowing Owls, and estimated an overall density of nesting Burrowing Owls of approximately 0.12 owls/km^2 He also found that 66% of the nests occurred in black-tailed prairie dog colonies, although those colonies made up <20% of the total landscape surveyed. Burrowing Owl densities varied greatly between those owls occupying black-tailed prairie dog colonies (38.1 owls/km^2) and those at least 1.6 km from black-tailed prairie dog colonies (0.04 owls/km^2). All Burrowing Owl nests were found in vegetation that was <10 cm in height (Butts 1971).

According to the Oklahoma Breeding Bird Atlas (OBBA) conducted through the 2001 field season, Burrowing Owls were recorded in 32 of the 42 OBBA blocks (1.86 $\times$ 2.17 km) surveyed in the Oklahoma panhandle that also had at least one prairie dog colony (D. Reinking pers. comm.). This included 9 of 11 blocks for Beaver County, 11 of 16 for Texas County, and 12 of 15 for Cimarron County. In addition to the above, nesting records exist for Grant, Cleveland, Oklahoma, Canadian, Custer, Blaine, Woods, and Alfalfa counties. The latter records, however, ranged in date from 1909–65, and it is not clear how many of these represent annual nesting attempts by established populations opposed to accidental or occasional nesting attempts. Baumgartner and Baumgartner (1992) in-

Figure 1. Breeding range (shown in gray) of the Burrowing Owl in Oklahoma, as determined by Breeding Bird Survey data (1966–99), other breeding records, and personal observations. Gray areas denote regular breeding range.

dicated that the Burrowing Owl was not a regular breeding species in central Oklahoma prior to European settlement.

Breeding Bird Survey (BBS) data indicate that Burrowing Owls occur in many of the western counties in Oklahoma (Sauer et al. 2000). The BBS data indicate that relative abundance of Burrowing Owls is low (range 0.13–1.95) for all four physiographic regions of the state. Analysis of these data demonstrate that Burrowing Owl numbers in Oklahoma declined by 12.3% per yr during the 34-yr period from 1966–99. BBS data quality for Burrowing Owls, although less than optimal due to the relatively small number of BBS routes in the state, is nonetheless the most useful data available for determining population trends of this species in Oklahoma.

WINTERING RECORDS

The current wintering range of the Burrowing Owl is restricted to western Oklahoma (Fig. 2), based on Christmas Bird Count (CBC) data, other wintering records, and personal observations (1930–99). Most Burrowing Owls migrate south from Oklahoma in the fall (usually October) and some winter as far south as central Mexico (Butts 1976, G. Holroyd pers. comm.). Therefore, Burrowing Owls are considered either rare winter residents or are very secretive in the panhandle and the northern tier of counties in Oklahoma (Butts 1976). The winter can be relatively severe in northern Oklahoma, and Burrowing Owls facing these conditions generally migrate south for the winter. In the southwestern counties of Oklahoma, owls are considered occasional winter residents (Baumgartner and Baumgartner 1992). The survey by Butts (1976) allowed a comparison of summer and winter Burrowing Owl numbers. He surveyed an area of 4367 km^2 in the eastern panhandle and found 543 adult owls during the 1970 breeding season and 527 adult owls during the 1971 breeding season. However, he located only six owls in the same area during the 1970–71 winter (ca. 1% of the summer population).

Burrowing Owls have been recorded on CBCs at Kenton (Black Mesa), Cimarron County, Arnett (Ellis County), Oklahoma City, Oklahoma County, and Norman (Cleveland County). There have never been more than a few individuals reported from any count. In addition to winter records in the western counties, there are winter records of Burrowing Owls for a number of scattered counties in other areas of Oklahoma, including Oklahoma, Muskogee, Garvin, Tulsa, Pawnee, Payne, and Washington counties (Baumgartner and Baumgartner 1992, Sauer et al. 1996). The winter distribution of Burrowing Owls is broader than their breeding distribution in Oklahoma (Figs. 1, 2) and may be due, at least in part, to stopover of migrants

Figure 2. Non-breeding range of the Burrowing Owl in Oklahoma, as determined by Christmas Bird Count data (1930–99), other wintering records, and personal observations. Dark gray area denotes regular winter range, light gray areas denote extra-limital winter records.

from more northern parts of the range. A similar pattern of winter distribution in Texas and Mexico offers some evidence for this idea (G. Holroyd pers. comm.).

STATUS OF PRAIRIE DOGS IN OKLAHOMA

In Oklahoma, black-tailed prairie dog colonies once covered approximately 400 000 ha, but now exist only in scattered, disjunct populations (U.S. Fish and Wildlife Service 2000). Tyler (1968) reported that millions of hectares of prairie dog colonies were found historically in Oklahoma, but that by 1968, the total area of colonies had been reduced to 3856 ha. Historically, black-tailed prairie dogs were locally common and widespread in the western-most counties, including Cimarron, Texas, Beaver, Harper, and Ellis counties, but became less common eastward into the mixed-grass prairie. Most of the decline of black-tailed prairie dogs (and presumably Burrowing Owls) occurred between 1885–1925. In recent years, populations of black-tailed prairie dogs in the Oklahoma panhandle have been unstable due to sylvatic plague and active eradication programs (U.S. Fish and Wildlife Service 2000, S. Sheffield pers. observ.).

A survey of prairie dog colonies was conducted in Oklahoma for the Oklahoma Department of Wildlife Conservation (ODWC) in 1988–89 (J. Shackford, J. Tyler, and L. Choate unpubl. data). More recently, ODWC game wardens conducted a follow-up survey in the fall of 1998. Of the 399 prairie dog colonies recorded by J. Shackford and colleagues, 313 of these were revisited. At least 110 previous unrecorded prairie dog colonies were found incidentally while trying to verify the locations of the previous survey. These new colonies probably are a combination of newly colonized sites, colonies that were small 10 yr ago, colonies missed by the 1988–89 survey, and colonies for which the legal description was incorrectly recorded in 1989 so that the colony was recorded as absent in 1998 and a "new" colony was found nearby. The minimum number of colonies present in 1998 was 302, though the actual number was probably closer to 380. Population sizes in colonies were not estimated in the 1998 survey, so trends cannot be determined.

In the main part of the state, the total number of prairie dog colonies appears to have declined by about 7% (ODWC unpubl. data). In Cimarron County, the number of prairie dog colonies is estimated to have declined by 34%. This may have been due, at least in part, to the plague outbreak that was documented there in 1991–92. However, the number of prairie dog colonies in the two other panhandle counties (Texas and Beaver) seems to have increased by 19%. In central Oklahoma, black-tailed prairie dog colonies apparently were rare but some were very large.

Association between Burrowing Owls and Black-tailed Prairie Dogs in Oklahoma

Tyler (1968) found 280 black-tailed prairie dog colonies in his Oklahoma survey, and found Burrowing Owls inhabiting 40% of the prairie dog colonies checked. The largest number of owls in a single dog colony was 30 individuals. Butts and Lewis (1982) found that, within prairie dog colonies, Burrowing Owls aggregated their nests into clusters and often concentrated nests at edges of black-tailed prairie dog colonies. Prairie dog colonies appeared to be the only habitat with sufficient densities of burrows to provide both nesting and satellite burrows. There may be a certain minimum area of prairie dog colony(ies) required for Burrowing Owls to nest, but this threshold is not known. J. Shackford (unpubl. data) found owls in regions of the state where there were at least seven individual prairie dog colonies or at least 162 ha of prairie dog colonies in close proximity. Black-tailed prairie dog colonies in Oklahoma became unsuitable for Burrowing Owls 1–3 yr after abandonment by black-tailed prairie dogs (Butts and Lewis 1982). They suggested that Burrowing Owls nesting outside of prairie dog colonies in Oklahoma were utilizing marginal habitat and may represent individuals forced out of preferred prairie dog colony habitat (Butts and Lewis 1982).

Barko et al. (1999) found that Burrowing Owl abundance was significantly higher on sites with black-tailed prairie dog colonies than at uncolonized sites in Oklahoma during the spring and summer. They recorded Burrowing Owls on prairie dog-colonized sites of 3–302 ha ($N = 5$). Desmond et al. (2000) found strong correlations between Burrowing Owl and black-tailed prairie dog declines and provided evidence of a time lag in Burrowing Owl population response to changes in active burrow densities of prairie dogs in Nebraska between 1990–96.

In Oklahoma, there has been great variation in Burrowing Owl occupation of large versus small prairie dog colonies. Butts (1971) found a large range in the density of nesting Burrowing Owls in prairie dog colonies. He found that large colonies (>40.5 ha) in Beaver County did not have Burrowing Owls, but 19 of 21 colonies that were <4 ha in size supported Burrowing Owls. Tyler (1968) found a 1.2 ha prairie dog colony in Jackson County with 30 Burrowing Owls. These data indicate that Burrowing Owls will utilize small colonies. Therefore, assumption that larger prairie dog colonies are more likely to contain Burrowing Owls does not appear to be valid in all cases. There is some evidence that Burrowing Owls are easier to detect in smaller prairie dog colonies or colonies with fewer prairie dogs (M. Desmond and M. Restani pers. comm.).

Burrowing Owls have coevolved with prairie dogs and other colonial sciurids in the prairie grassland ecosystem in North America. They have been found to be tightly associated with prairie dog colonies in Oklahoma (Tyler 1968), Nebraska (Desmond and Savidge 1996), South Dakota (Sharps and Uresk 1990), and Wyoming (Campbell and Clark 1981). In addition, Clark et al. (1982) found a strong correlation between increased vertebrate abundance and increased colony size ($r = 0.81$). Prairie dog colonies provide heterogeneous plant cover, high densities of prey species, high seed production, low vegetation height, and good visibility of prey and predators (Clark et al. 1982). One main benefit of this close association for both owls and prairie dogs appears to be increased protection from predation (Desmond et al. 2000).

Clearly, black-tailed prairie dog colonies are critically important to Burrowing Owls in Oklahoma, as well as in much of the rest of midwestern North America (Butts and Lewis 1982). However, Burrowing Owl populations have suffered in Oklahoma because of their close ecological association with black-tailed prairie dogs. Although both black-tailed prairie dogs and Burrowing Owls were considered locally common in the state prior to European settlement, both species were virtually wiped out by a statewide poisoning campaign in 1922 (Baumgartner and Baumgartner 1992).

Outlook for Burrowing Owls in Oklahoma

Burrowing Owls should be able to persist in the panhandle and in other western counties of Oklahoma, where there is relatively little development and where habitat has not been greatly altered. However, one problem area is Cimarron County, where the major loss of prairie dog colonies is cause for concern. Prairie dog colonies in Oklahoma should be monitored closely at least every 2–4 yr, including monitoring of both Burrowing Owls and prairie dogs. If the focus of conservation efforts is on the prairie dog/grassland ecosystem, then there is a good chance that the Burrowing Owl also will be protected in

Oklahoma. Major cooperative efforts are needed to ensure that viable populations of both species continue to exist throughout their ranges in Oklahoma so that they do not continue to decline toward endangered status.

Most of the nearly 400 prairie dog colonies in Oklahoma occur on private lands. This is of concern because there is a greater likelihood of habitat alteration and less ability to enact conservation actions on private lands. State-sponsored initiatives to conserve prairie dog colonies on private lands would address this situation.

In 2000, the ODWC began aerial transect surveys of prairie dog colonies in Cimarron, Texas, Beaver, Harper, and Ellis counties, and in 2002 will attempt to ground-truth colonies that were identified during the aerial survey. Burrowing Owls will be monitored during this effort.

Finally, Burrowing Owl mortality factors, such as pesticide poisoning, can be significant in some areas of Oklahoma, particularly in agricultural and rangeland areas where pesticides are applied, and both direct and secondary poisoning can occur (Sheffield 1997b). Conservation and management measures, education, and changes in both public attitudes and policies are necessary for the continued existence of viable populations of Burrowing Owls and grassland sciurids in Oklahoma and in North America in general (Holroyd et al. 2001).

ACKNOWLEDGMENTS

We thank J.S. Shackford, J.D. Tyler, and L.L. Choate for information on black-tailed prairie dogs in Oklahoma, D. Reinking for information on Burrowing Owls and prairie dogs seen during the Oklahoma Breeding Bird Atlas, M.J. Desmond, S.W. Gillihan, T.I. Wellicome, and an anonymous reviewer for providing helpful comments on this paper, and G.L. Holroyd for his efforts in organizing the 2nd International Burrowing Owl Symposium in Ogden, Utah.

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J Raptor Res. 35(4):357–361

DISTRIBUTION OF BURROWING OWLS ON PUBLIC AND PRIVATE LANDS IN COLORADO

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Abstract.—Burrowing Owls (*Athene cunicularia hypugaea*) in Colorado occur primarily on the eastern plains, with smaller populations in grasslands of the western and central regions of the state. As part of a regional project to conserve shortgrass prairie, we surveyed eastern Colorado for Burrowing Owls. We identified 423 Burrowing Owl locations, and received information on an additional 46 locations in parts of the state that we did not survey. Eighty percent of Burrowing Owl locations were on prairie dog (*Cynomys* spp.) colonies. Our findings reinforce the important link between prairie dog populations and Burrowing Owl populations, and the need to enlist private landowners in conservation efforts.

Key Words: *Burrowing Owl;* Athene cunicularia hypugaea; *prairie dog;* Cynomys ludovicianus; *distribution; survey; private lands; Colorado.*

Distribución de Buhos Cavadores en terrenos publicos y privados en Colorado

Resumen.—Los Búhos Cavadores (*Athene cunicularia hypugaea*) en Colorado ocurren en primer lugar en las llanuras orientales, con las mas pequeñas poblaciones en los pastizales de las regiones occidentales y centrales del estado. Como parte de un proyecto regional para conservar praderas de pastos cortos, examinamos el oriente de Colorado en busca de Búhos Cavadores. Identificamos 423 localidades con Búhos Cavadores, y recibimos información de 46 localidades mas, en partes del estado que no estudiamos. Ochenta por ciento de las localidades del Búho Cavador estaban en colonias de perros de la pradera (*Cynomys* spp.). Nuestros hallazgos reforzaron el importante lazo entre las poblaciones de perros de la pradera y las del Búho Cavador, y la necesidad de enrolar terratenientes privados en los esfuerzos de conservación.

[Traducción de Victor Vanegas y César Márquez]

The Western Burrowing Owl (*Athene cunicularia hypugaea*) is listed as Endangered in Canada, Threatened in Colorado, and a Sensitive Species in U.S. Forest Service Region 2, which includes Colorado. The geographic center of the Burrowing Owl breeding range is Colorado (Wellicome and Holroyd 2001), where populations are concentrated on the eastern plains, with smaller populations in south-central and west-central sections of the state (Andrews and Righter 1992, Jones 1998). Historical records are sparse, but Burrowing Owls were formerly common locally on the prairies of eastern and western Colorado (Bailey and Niedrach 1965). Accurate population estimates and trends for Burrowing Owls are lacking (Robbins et al. 1986), but over half of the state and provincial wildlife agencies with jurisdiction within the range of the Burrowing Owl recently reported declining populations, and none reported an increasing population (James and Espie 1997). The only long-term data set available for Colorado, the Breeding Bird Survey, shows no statistically significant trend for the entire period that the survey has been run, 1966–99 ($P = 0.52$; $N = 35$ routes), although a significant rate of increase (10.31% per yr) is apparent for more recent periods (1985–98; $P = 0.03$; $N = 33$ routes; J.R. Sauer et al. 2000).

Approximately 40% of the historical shortgrass prairie in Colorado was lost by 1970 (Colorado Division of Wildlife unpubl. data). Habitat loss for Burrowing Owls continues statewide, with human development estimated to convert 17 637 ha/yr between 1990–2020, based on projected population growth (Hobbs and Theobald 1998). Populations of Burrowing Owls have been extirpated from much of the heavily-populated Front Range, which lies at the base of the eastern foothills (Niedrach and Rockwell 1939, Bailey and Niedrach 1965). Owl populations in counties east of the foothills are less threatened by urban expansion, but loss of

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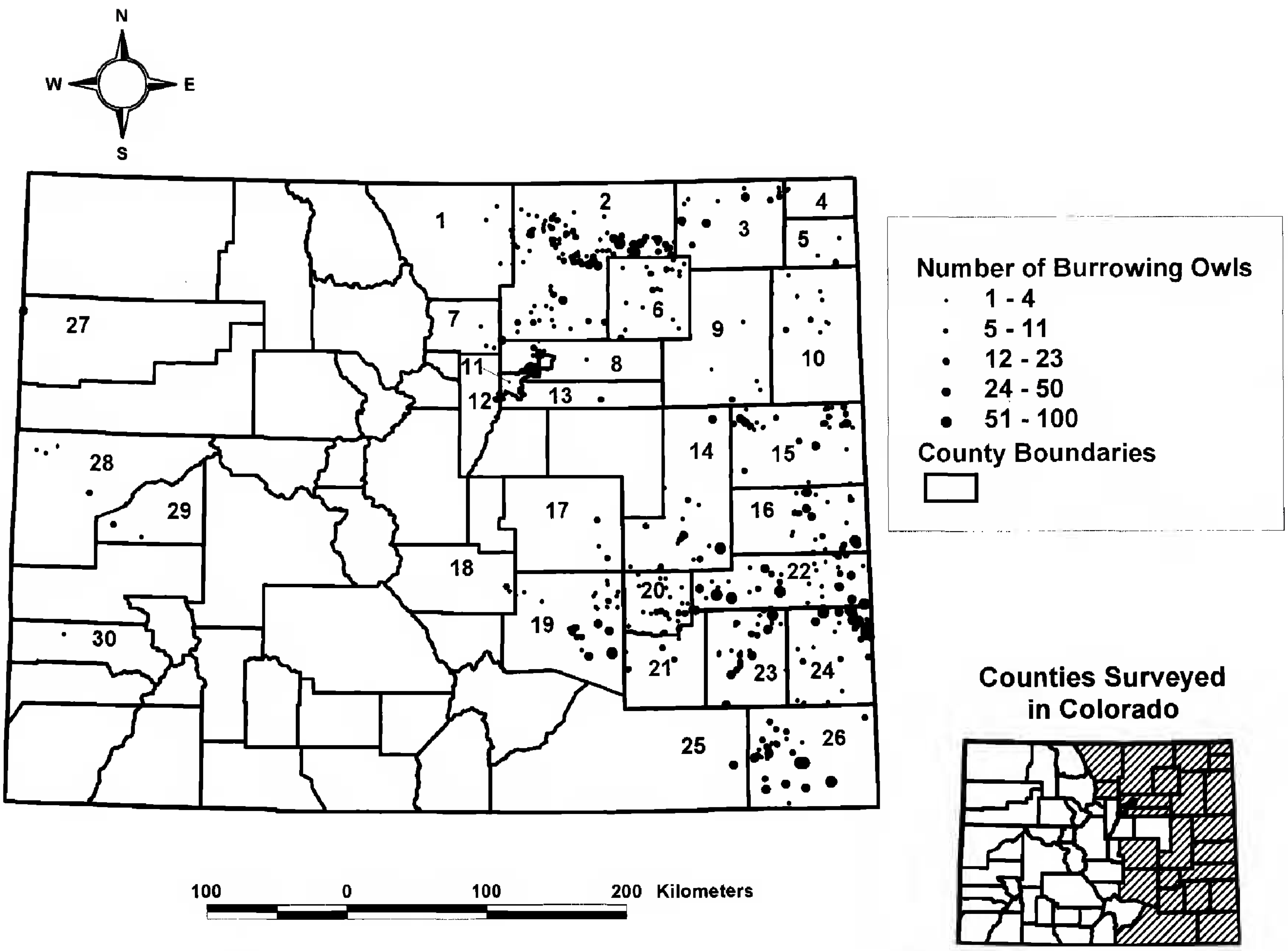

Figure 1. Burrowing Owl numbers and distribution in Colorado, 1999, as determined by the Rocky Mountain Bird Observatory Prairie Partners Project. Counties: 1 = Larimer, 2 = Weld, 3 = Logan, 4 = Sedgwick, 5 = Phillips, 6 = Morgan, 7 = Boulder, 8 = Adams, 9 = Washington, 10 = Yuma, 11 = Denver, 12 = Jefferson, 13 = Arapahoe, 14 = Lincoln, 15 = Kit Carson, 16 = Cheyenne, 17 = El Paso, 18 = Fremont, 19 = Pueblo, 20 = Crowley, 21 = Otero, 22 = Kiowa, 23 = Bent, 24 = Prowers, 25 = Las Animas, 26 = Baca, 27 = Rio Blanco, 28 = Mesa, 29 = Delta, 30 = San Miguel.

habitat to cultivation, ranchette development, and widespread control of prairie dogs (*Cynomys* spp.) still pose threats.

Throughout much of their range, western Burrowing Owls are closely associated with prairie dog colonies, which provide nesting and foraging habitat (Haug et al. 1993). Black-tailed prairie dogs (*Cynomys ludovicianus*) may have occupied as much as 1 860 000 ha in Colorado before settlement by European-Americans, but their range had declined by the late-1970s to an estimated 36 000 ha, a decline of 98% (W. Van Pelt, Arizona Game and Fish Dept. publ. comm.). Colorado state wildlife laws currently classify the prairie dog as a small game species; hunting is allowed year-round with no bag or possession limits, and landowners are allowed to use chemical or other means to control prairie dogs on their lands (W. Van Pelt, Arizona Game and Fish Dept. publ. comm.). Regulations that take effect in September 2001 will prohibit sport hunting of black-tailed prairie dogs in eastern Colorado, but landowners will still be allowed to control prairie dogs that they perceive are damaging their land.

In 1998, Rocky Mountain Bird Observatory (RMBO) initiated the Prairie Partners Program, with the primary objectives of identifying important habitat for shortgrass-prairie birds and developing long-term voluntary conservation agreements with private landowners. As part of the Prairie Partners Program, we surveyed eastern Colorado for Burrowing Owls.

METHODS

We surveyed for Burrowing Owls east of the foothills in Colorado (Fig. 1) from 15 April–31 August 1999. Most surveys were conducted between 1 May–31 July. This period covered the breeding season for Burrowing Owls in Colorado (Jones 1998). We surveyed private land, state wildlife and recreation areas, state land board sections, and federal lands where Burrowing Owls were not surveyed by natural resource agencies. We used roadside surveys to locate owls, with efforts concentrated on prairie dog colonies and other Burrowing Owl habitats (e.g., mid-grass and shortgrass prairie). The use of roadside surveys, rather than more intensive methods, allowed us to conduct broad-scale surveys of eastern Colorado within a single breeding season.

Because Burrowing Owls are active during the day, as well as the night (Haug et al. 1993), we surveyed from sunrise until mid-morning and late-afternoon until sunset. We drove roads at moderate speeds, 50–65 km/hr, typically with one observer per vehicle. We did not survey when winds exceeded 30 km/hr or when it was raining. While driving, we scanned the area visible from the road for prairie dog colonies, mid-grass and shortgrass prairie, and owls. We also scanned fence posts and utility poles for perched owls. If owls or any burrows were observed, we stopped and scanned the area with binoculars or spotting scopes. We monitored the area for 10–15 min to count owls (adults and young-of-the-year), and recorded the maximum number seen, taking care not to double-count individuals. We marked owl locations on maps, and used Global Positioning System receivers to collect location data for uploading to a Geographical Information System (GIS) database. We also recorded the occurrence of prairie dogs and the land-ownership category.

We used a land-ownership layer for the state of Colorado (Natural Diversity Information Source 2000) in ArcView GIS (Environmental Systems Research Institute Inc. 1996) to determine how much area was owned by different entities within the state. We only quantified area of land by ownership for the counties occupied by Burrowing Owls.

We supplemented our data with additional information on owl locations from the Colorado Division of Wildlife, Rocky Mountain Arsenal National Wildlife Refuge, Pawnee National Grasslands, Comanche National Grasslands, Chatfield State Park, the Colorado Natural Heritage Program, Rocky Mountain Bird Observatory's *Monitoring Colorado's Birds* project, Prairie Partners Program cooperators, and amateur birders. We often revisited these areas to confirm Burrowing Owl sightings.

RESULTS

Fourteen people, including RMBO staff and volunteers, surveyed for Burrowing Owls in eastern Colorado for >2000 hr in total. This estimate does not include time spent by biologists and amateur birders who provided additional sightings. We identified 423 Burrowing Owl locations in eastern Colorado, and our cooperators identified an additional 46 owl locations in areas that we did not survey (Table 1, Fig. 1). These results do not include Fort Carson military base, Montezuma County, South Park, North Park, and the San Luis Valley, where owl locations had been documented previously (Jones 1998); no counts have been conducted recently in these areas. Most owl locations (79.3%) were on private lands (Table 1). Owl locations were distributed unevenly across counties (Fig. 1, Table 2). Eighty percent of Burrowing Owl locations were on prairie dog colonies.

Table 1. Land-ownership categories for known Burrowing Owl locations in Colorado, 1999.

LAND OWNERSHIP	NO. OF OWL LOCATIONS	PERCENT OF TOTAL
Private	372	79.3
State land board	33	7.0
U.S. Forest Service National Grasslands	32	6.8
U.S. Dept. Interior Bureau of Land Management	10	2.0
Other federal	8	1.7
City	6	1.3
County	5	1.1
State	3	0.6

DISCUSSION

Our surveys were conducted from the arrival of owls in spring until young were ready to fledge, so areas surveyed early in the season, when young were not yet visible above ground, had lower owl counts than those late in the season. Thus, we could not compare numbers of owls observed across the breeding season, and have presented information on owl counts primarily to show owl distribution (Fig. 1).

Weld County had the greatest number of Burrowing Owl locations (Table 2). Weld was the largest county surveyed and ranked third for total area of grassland among eastern Colorado counties (Colorado Division of Wildlife unpubl. data). Also, Weld ranked second for area of active black-tailed prairie dog colonies in eastern Colorado (Colorado Division of Wildlife unpubl. data).

Burrowing Owls exhibit a close association with prairie dog colonies, which provide nesting and foraging habitat (Haug et al. 1993). Prairie dog alarm calls may facilitate more effective predator detection by Burrowing Owls, and prairie dogs may serve as an alternative prey for predators, helping reduce the risk of predation on Burrowing Owls

Table 2. Distribution of known Burrowing Owl locations by county in Colorado, 1999.

County	Owl Locations	Percent of Owl Locations
Adams	11	2.3
Arapahoe	1	0.2
Baca	29	6.2
Bent	26	5.5
Boulder	3	0.6
Cheyenne	23	4.9
Crowley	24	5.1
Delta	2	0.4
Denver	3	0.6
El Paso	3	0.6
Fremont	2	0.4
Jefferson	1	0.2
Kit Carson	32	6.8
Kiowa	37	7.9
Las Animas	1	0.2
Larimer	9	1.9
Lincoln	17	3.6
Logan	16	3.4
Mesa	4	0.8
Morgan	18	3.8
Otero	8	1.7
Phillips	3	0.6
Prowers	33	7.0
Pueblo	33	7.0
Rio Blanco	1	0.2
San Miguel	1	0.2
Sedgwick	2	0.4
Washington	5	1.1
Weld	111	23.7
Yuma	10	2.1

(Desmond et al. 2000). Burrowing Owls often distribute broods among several burrows within a prairie dog colony, making it less likely to lose an entire brood to predation (Desmond and Savidge 1999). Because of these relationships, any effective conservation strategy for Burrowing Owls in the state must address conservation of prairie dogs.

Our sampling did not yield an accurate estimate of the total Burrowing Owl population in Colorado, but identified hundreds of Burrowing Owl locations, many of which had not been documented previously. This study helps fill the gap in information that exists on private lands and establishes a baseline upon which future studies and management can build. It also helps state and local officials, resource managers, and researchers gain a better understanding of the Burrowing Owl population and its distribution within Colorado.

Because the vast majority (79.3%) of owl locations in this study were on private lands, a long-term approach that promotes prairie stewardship on private lands appears to be key for Burrowing Owl protection. Burrowing Owl conservation can be enhanced through programs such as Prairie Partners, which asks private landowners for their voluntary cooperation to protect shortgrass prairie birds and their habitat (Skeel et al. 2001). The state land board and the U.S. Forest Service National Grasslands supported the second highest number of owl locations in this study. State land board sections generate revenue for public education, primarily through agricultural leases to the private sector for grazing and crop production, and also through mineral development. Because state land board lands are managed by private leasees, private landowners and the Forest Service are the most important stewards of Burrowing Owl habitat in Colorado. Given that the National Grasslands are interspersed with private parcels, cooperative management between the Forest Service and private landowners would encourage management of the areas as comprehensive units, rather than separate, fragmented parcels. Such cooperative land management would undoubtedly enhance Burrowing Owl conservation.

ACKNOWLEDGMENTS

Field workers included M. Carter, A. Crawford, D. Faulkner, D. Hanni, H. Kahler, N. Komar, A. Leukering, T. Leukering, R. Levad, J. Parrot, A. Versaw, A. Wagner, and S. York. J. Woodard generously shared his data on private lands surrounding the Pawnee National Grasslands. Additional information came from M. Ball, M. Hetrick, H. Kahler, M. Sattelberg, and D. Weber. The Conservation Technology Support Program donated the GIS software. We thank T.I. Wellicome for this publication opportunity. We thank L. Ayers, D. Plumpton, and M Restani for reviewing the manuscript critically. We are most grateful to the many private landowners who provided us with local information about owls and allowed us access to their land.

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J Raptor Res. 35(4):362–370

ANALYSES OF BURROWING OWL POPULATIONS IN NEW MEXICO

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Abstract.—Populations of western Burrowing Owls (*Athene cunicularia hypugaea)* in New Mexico were assessed using a variety of approaches: 1) multi-year studies at three specific sites; 2) a single-season survey of prairie dog (*Cynomys* spp.) colonies in five northeastern counties; 3) a questionnaire to state and federal agencies, private organizations, and biologists throughout the state; 4) analysis of North American Breeding Bird Survey results from 1968–2000; 5) owl counts at prairie dog re-establishment sites; and 6) incidental reports and other sightings. Owl populations in some areas were reportedly stable or increasing, but were decreasing in other areas. Factors most often reported to be associated with stable or increasing populations were food availability, suitable habitat (including the presence of prairie dogs), and increased precipitation. Declining populations appeared to suffer from loss of suitable nesting habitat, caused either by disappearance of prairie dog colonies or by urban sprawl into arid lands and farmland. Declining populations also suffered from high predation, persecution, or disturbance by rock squirrels (*Spermophilus variegatus*). In some cases, the causes for declines were unknown. Overall, the data suggest moderate concern for Burrowing Owl populations in New Mexico.

Key Words: *Burrowing Owl*; Athene cunicularia hypugaea; *population trend*; *agency survey*; *prairie dog*; Cynomys *spp.*; New Mexico.

Analisis de las poblaciones del Búho Cavador en nuevo México

Resumen.—Las poblaciones de los Búhos Cavadores Occidentales (*Athene cunicularia hypugaea)* en Nuevo México fueron evaluadas utilizando una variedad de métodos: 1) Estudios de múltiples años en tres sitios específicos; 2) Un estudio de una sola estación de las colonias de perros de la pradera (*Cynomys* spp.) en cinco condados nororientales; 3) Un cuestionario para agencias estatales y federales, organizaciones privadas, y biólogos a lo largo del estado; 4) Analisis de los resultados del Monitoreo Americano de Reproduccion desde 1968–2000; 5) Conteo de búhos en sitios de re-establecimiento de perros de la pradera; y 6) Reportes incidentales y otros avistamientos. Las poblaciones de búhos en algunas áreas fueron reportadas como estables o en incremento, pero estaban decreciendo en otros lugares. A menudo los factores reportados mas asociados con poblaciones estables o en aumento fueron la disponibilidad de comida, hábitat adecuado (que incluye la presencia de perros de la pradera), y el incremento de la precipitación. Las poblaciones en declive parecían sufrir de perdida del hábitat de anidación adecuado, causado ya sea por la desaparición de las colonias de perros de la pradera o por la expansión urbana dentro de tierras áridas y de cultivo. Las poblaciones declinantes sufrían además de alta depredación, persecución, o perturbación por parte de ardillas de roca (*Spermophilus variegatus*). En algunos casos, las causas del decline fueron desconocidos. En conjunto, los datos sugieren una preocupación moderada para las poblaciones del Búho Cavador en Nuevo México.

[Traducción de Victor Vanegas y César Márquez]

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The western Burrowing Owl (*Athene cunicularia hypugaea*) is referred to as a 'high responsibility species' by U.S. National Partners in Flight. That classification is based on trends from North American Breeding Bird Survey data and the percent of the species' breeding range within western physiographic areas. In this paper, we provide information about population trends at three locations, report population numbers from a single-season survey of five counties in northeastern New Mexico, summarize responses to a questionnaire we sent to various agencies throughout the state, summarize Burrowing Owl data from the North American Breeding Bird Survey (1968–2000), and report data from other sites, including three sites where prairie dog colonies have been re-established.

Physiography of New Mexico. We used physiographic areas to evaluate the state with respect to potential for Burrowing Owls. New Mexico is physically and biotically diverse, consisting of deserts, plateaus, mountain ranges up to 4011 m high (some with extensive forests), rivers, grasslands, and farmland. The lowest elevation is 866 m, in the southeastern part of the state. The state has a total area of 311 478 km^2. Tectogenic events have affected primarily the western two-thirds of the state, resulting in mountains, mesas, plateaus, valleys, and basins. The eastern one-third of the state is a relatively level plain (Findley et al. 1975). Despite this physical diversity, the state can still be classified as mostly grassland (Findley et al. 1975).

Ecozones known to have Burrowing Owls or to have the potential for Burrowing Owls are found throughout the state (Fig. 1). The ecozones were identified from Dick-Peddie's (1993) classification of 16 ecological zones in New Mexico. The 10 ecological zones identified as known or potential owl sites comprise 74.9% (233 226 km^2) of the state's area; the six unlikely owl ecological zones comprise 25.1% (78 252 km^2) of the state's area (Dick-Peddie 1993 cited in Thompson et al. 1996).

In these known/potential ecozones, the owls may use or enlarge the burrows of various solitary or colonial mammals, including prairie dogs (*Cynomys ludovicianus, Cynomys gunnisoni*), kangaroo rats (*Dipodomys ordii, D. spectabilis*), hares and rabbits (*Lepus californicus, Sylvilagus audubonii, S. floridanus*), squirrels and chipmunks (*Spermophilus variegatus, S. lateralis, S. tridecemlineatus, S. spilosoma, S. mexicanus, Ammospermophilus leucurus, Eutamias quadrivittatus*), pocket gophers (*Thomomys talpoides, T. bottae, Geomys bursarius, Pappogeomys castanops*), skunks (*Spilogale gracilis, Mephitis mephitis, Conepatus mesoleucus*), badgers (*Taxidea taxus*), and possibly rats (*Sigmodon hispidus, Neotoma micropus*; classification by Findley et al. 1975). Miscellaneous burrow sites that are more unusual include pipes laying on the ground, drainage pipes in rock walls, crevices under concrete walks or buildings, and inside interstate highway interchanges (P. Arrowood, C. Blood, C. Finley pers. observ.). In towns and cities, Burrowing Owls are found in parks, lawns, campuses, the upper edges of drainage arroyos, and the banks of irrigation canals (P. Arrowood pers. observ.). Rarely, the owls dig their own burrows by scratching with their feet in soft dirt (pers. observ.). It is well known that Burrowing Owls prefer burrows that are in more open habitat (Haug et al. 1993). Thus, some of the potential habitat shown in New Mexico (Fig. 1) may not be used because of dense stands of mesquite (*Prosopis glandulosa, P. pubescens*), creosote bush (*Larrea tridentata*) or other tall vegetation; however, banks and other open areas that provide acceptable nesting sites sometimes occur within such habitats.

STUDY AREAS AND METHODS

Sites Studied for Multiple Years. The most intensively surveyed or studied areas in New Mexico include the New Mexico State University campus (NMSU) in Las Cruces (Botelho 1996, Botelho and Arrowood 1996, 1998), Holloman Air Force Base near the city of Alamogordo (K. Johnson, L. Delay, P. Mehlhop, K. Score unpubl. data, Hawks Aloft Inc. unpubl. data), and Kirtland Air Force Base (Hawks Aloft Inc. unpubl. data) in Albuquerque (Fig. 1).

Burrowing Owl research began at NMSU in 1993 (Botelho 1996, Botelho and Arrowood 1996, 1998) and has continued to the present. Adult Burrowing Owls and their offspring were found while driving campus streets and walking through the football stadium and athletic fields, the old landfill, a flood control dam and nearby desert vegetation, and irrigated pastures two to three times/week. Owls were counted on the 364 ha campus in every year, except 1996, and attempts were made to band every bird. All burrows that were used, even temporarily, were marked with special posts. We and the NMSU Physical Plant Department maintained maps of all marked burrows. Burrows that were to be affected by construction were identified well in advance, and replacement artificial burrows were installed as close to the original burrows as possible.

Holloman Air Force Base is located in the Tularosa Basin near Alamogordo (Fig. 1). To determine Burrowing Owl numbers, K. Johnson, L. Delay, P. Mehlhop, K. Score in 1996–97 (unpubl. data) and Hawks Aloft Inc. in 2000 (unpubl. data) did 15 m transects through two general areas (airway taxiways and a high-speed land test track) where Burrowing Owls had occurred historically.

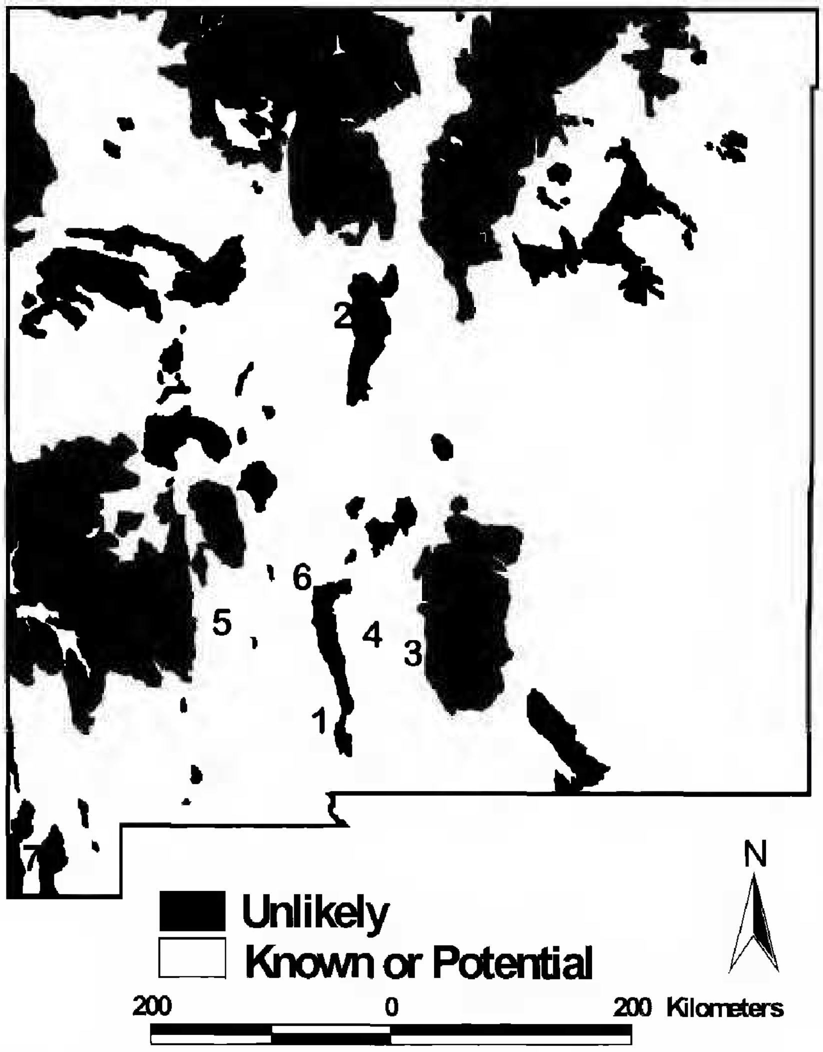

Figure 1. Map of New Mexico showing known or potential ecozones (Dick-Peddie 1993) with Burrowing Owls, including Chihuahuan desert scrub, closed basin scrub, desert grassland, Great Basin desert scrub, juniper savanna, lava beds, plains-mesa grassland, plains-mesa sand scrub, sand dunes, urban and farmland. Ecozones unlikely to support owls include alpine tundra, coniferous and mixed woodland, montane coniferous forest, montane grassland, montane scrub, and subalpine coniferous forest. Numbers indicate the locations of the following sites: 1—New Mexico State University, 2—Kirtland Air Force Base, 3—Holloman Air Force Base, 4—White Sands Missile Range, 5—Ladder Ranch, 6—Armendaris Ranch, 7—Gray Ranch.

Kirtland Air Force Base in Albuquerque (Fig. 1) has the largest population of Burrowing Owls studied in New Mexico (C. Finley and N. Cox pers. observ.). The number and location of all owls has been monitored each year since 1998 by Hawks Aloft Inc. and the base biologist. During daily surveys (5 days/week, early morning or early evening) all areas known to have had owls were driven by car from late February–May. Large areas could be seen from the vehicle so no transects were done.

Single-Season Survey of Five Northeastern Counties. The Rocky Mountain Bird Observatory (formerly the Colorado Bird Observatory) is a non-profit conservation organization whose program, Prairie Partners, is an effort to assess the status of avian prairie-linked species in Wyoming, Montana, Colorado, and New Mexico. The observatory employed C. Finley to survey systematically for Burrowing Owls at prairie dog colonies in five northeastern New Mexico counties (Union, Colfax, Harding, Quay, and San Miguel) in early summer 1998. To locate prairie dog colonies, Finley drove state and county roads When a colony was located, the landowner was contacted for permission to visit the colony to search for Burrowing Owls (see VerCauteren et al. 2001 for methodology). No distinction was made between adults and young.

Owl Survey by Questionnaire. In 1998, a questionnaire was e-mailed to 15 state and federal agencies, private organizations, and biologists throughout the state. We asked the following: 1) Can you briefly describe the geographic area in which you have populations of Burrowing Owls? 2) In that area, are the populations urban, rural, or both? 3) What is the estimated number of owls in the area? 4) Have Burrowing Owl numbers remained stable, increased, or decreased during the last five years in the area you described? 5) What do you believe are the factors responsible for any change you have noted? Most people who responded to the survey were also contacted by telephone to review their responses.

North American Breeding Bird Survey. Data on Burrowing Owl numbers were gathered from the BBS routes in New Mexico from 1968–2000 and analyzed for trends (Sauer et al. 2001).

Burrowing Owls at Prairie Dog Re-establishment Sites. At the Ladder Ranch (Fig. 1), ca. 6 km west of the city of Truth or Consequences, a program began in 1995 to re-establish black-tailed prairie dogs (*Cynomys ludovicianus*). Prairie dogs were re-established at three locations. At the Armendaris Ranch, ca. 25 km northeast of Truth or Consequences, six colonies of black-tailed prairie dogs have also been re-established. In addition, black-tailed prairie dogs have been re-established in parts of the former Gray Ranch (1300 km^2) in the Animas Mountain region in the southwestern "boot heel" of New Mexico, now managed by the Malpai Borderlands Group.

RESULTS

Sites Studied for Multiple Years. New Mexico State University: Despite the maintenance of a near constant number of burrows, the population of breeding Burrowing Owls varied considerably over the course of our study (Table 1). In particular, large declines in the number of nesting pairs occurred between 1995–97 and between 1998–99. We do not know what caused these declines, but we outline here at least two of the potential factors.

In February 1998, an old landfill with many crevices and burrows dug by squirrels (Botelho 1996, Botelho and Arrowood 1998) was filled so that most potential owl nesting sites were eliminated. Because the landfill had contained 24 pairs in 1 yr (Botelho and Arrowood 1998), the university installed 24 artificial burrows nearby (at sites determined by P. Arrowood) to replace burrows lost in the landfill. Noticeable drops in the number of

Table 1. Numbers of pairs and reproductive success of Burrowing Owls on the New Mexico State University campus, Las Cruces.

Year	No. Breeding Pairs	No. Nestlings	Mean No. Nestlings/Pair
1993[a]	24	40	1.67
1994[a]	19	65	3.42
1995[a]	30	42	1.40
1996	—	—	—
1997	14	48	3.43
1998[b]	16	24	1.50
1999[b]	4	18	4.50
2000	9	31	3.44

[a] Years from Botelho (1996).
[b] Years of increased sightings of rock squirrels.

breeding pairs occurred 1–2 yr before and 1 yr after the loss of the landfill burrows.

The Burrowing Owl population drop between 1998–99 also coincided with increased sightings of rock squirrels (*Spermophilus variegatus*) across campus (Table 1). Rock squirrels dig multiple burrows, some of which are used by the owls, but we suspect that these rather large (600–800 g) squirrels sometimes displace owls from burrows and eat owl eggs. In one brief experiment, Finley installed an artificial burrow in a rock squirrel colony and put pigeon eggs in the burrow chamber. A rock squirrel entered the burrow and emerged with an egg in its mouth. Although there were no owls there to defend the burrow, this experiment did document that squirrels eat eggs.

The squirrels are usually in hibernation when migrating male Burrowing Owls arrive and choose a burrow, but female owls arrive later and may therefore encounter active squirrels upon arrival (pers. observ.). However, few owl pairs have arrived on campus and then left, so the presence of rock squirrels does not directly explain the low number of owls that arrived on campus after 1998.

The number of young produced also varied among years (Table 1). In three of the seven study years, the mean number of nestlings produced per nesting pair was <2, and in the four remaining years, the mean was >3. Interestingly, whenever the mean number of nestlings per pair was <2, the population decreased in the following year, and whenever the mean was >3, the population increased in the following year.

Holloman Air Force Base: The number of pairs was 18 in 1996 and 19 in 1997 (K. Johnson, L. Delay, P. Mehlhop, and K. Score unpubl. data). The base biologist (H. Reiser pers. comm.) estimated that there was also this approximate number in 1998. A survey of all historically-occupied burrows found only two pairs and five young in 2000 (Hawks Aloft Inc. unpubl. data), a population decline of 89% since 1997. The decline was attributed to a loss of burrows. Some of the burrows available to the owls in 1996–97 had been created when pipelines were dug in the unique gypsum/clay soils, resulting in depressions and cavities. Some of these cavities were created and maintained by rock squirrels, badgers, and foxes. However, during the 2000 surveys, no signs of fresh badger diggings were observed and only a few rock squirrels were seen. Most of the burrows appeared to have collapsed internally.

Table 2. Numbers of pairs and reproductive success of Burrowing Owls on Kirtland Air Force Base, Albuquerque, New Mexico.

Year	No. Breeding Pairs	No. Pairs with Fledglings (%)	Total No. Fledglings	Mean No. Fledglings per Breeding Pair
1998	52	44 (85)	137	2.6
1999	48	39 (81)	125	2.6
2000	37	23 (62)	90	2.4

Kirtland Air Force Base: The owls are associated with colonies of Gunnison's prairie dogs (*Cynomys gunnisoni*), which occupy 441 ha on the base. Since 1998 (Table 2), numbers of breeding pairs, percent of pairs with fledglings, and total fledglings have all decreased; whereas, the number of fledglings per breeding pair has remained nearly constant. Abandonment of burrows (probably some containing clutches), sometimes apparently due to human disturbance, is one factor that led to the decline in percent of breeding pairs fledging young, but it does not account for the decline in the number of owls arriving each spring.

Single-Season Survey of Five Northeastern Counties. Finley saw Burrowing Owls at 36 of the 49 (73%) prairie dog colonies surveyed, for a total of 385 owls. Owls may have been present at other colonies but were not detected if they were inside burrows. The 385 owls recorded is much greater than any North American Breeding Bird Survey (BBS) single-year total for northeastern counties, or even for the state as a whole (see below). Of

Table 3. Summary of responses to a 1998 questionnaire about Burrowing Owl populations in New Mexico.

RESPONDENT AREA	COUNTY	DESCRIPTION	YEAR	NO. OWLS	STATUS[a]	FACTOR[b]
New Mexico State University	Dona Ana	Urban	1998	32	Un	Un
Las Cruces	Dona Ana	Urban	2000	68	Un	Un
White Sands Missile Range	Dona Ana	Rural	1997	1	Un	Un
			1998	4	Un	Un
	Otero	Rural	1998	2	Un	Un
Bureau of Land Management	7 counties	Both	1998	Un	S/I	H, F, OP, PC
Ladder Ranch	Sierra	Rural	1998	14	I	H, F
Armendaris Ranch	Sierra	Rural	2000	48	Un	Un
Private Organization	Bernalillo	Urban	1998	Un	D	LH
Private Organization	Santa Fe	Both	1998	Un	D	LH
Audubon Society	San Juan	Both	1998	Un	D	LH
Bureau of Land Management	Eddy	Both	1998	Un	I	Un
Jornada Experimental Range	Dona Ana	Rural	2000	6	Un	Un
Hawks Aloft Inc.	Taos	Rural	2000	2	Un	Un
	San Juan	Rural	2000	12	Un	Un

[a] S = stable, I = increasing, D = decreasing, Un = unknown.
[b] F = food, OP = owl persecution, PC = precipitation, H = good habitat, LH = loss of habitat, Un = unknown.

course, in Finley's survey, a greater proportion of the counties were surveyed than could be done by the BBS, more time was spent searching for owls at each colony, and Burrowing Owls were one of only three species being examined in the Prairie Partners work.

Owl Survey by Questionnaire. Survey results (Table 3) indicated that populations in three of the 14 areas (21%) are stable or increasing, three (21%) are decreasing, and eight (57%) are unknown (White Sands Missile Range reported for the same site in Dona Ana County in two different years). Stable and increasing populations were reported to have food and good habitat. Declining populations were thought to suffer from loss of habitat.

The Bureau of Land Management in Roswell reported for seven counties in east-central New Mexico where there are both urban and rural populations of owls. Rural populations have remained stable, while the urban populations appear to have increased near the city of Roswell. The agency felt that increased precipitation had resulted in increased seed supplies for rodents, which were responsible for the apparently stable to increasing owl populations. Even in that area, however, loss of burrows due to control of prairie dogs may have influenced Burrowing Owl populations.

White Sands Missile Range (Fig. 1) reported few owls given the size of the range (about 10 000 km^2). On an isolated site of several ha one pair and their two young were found in 1998. Only three other owls were reported from casual sightings on the missile range.

In the eight areas where owl numbers are listed as 'unknown,' no surveys or counts had been conducted, but biologists had reported casual observations in the areas and had formed impressions about whether or not there were changes in the populations.

North American Breeding Bird Survey. The state has 80 routes that were surveyed at least once during the 33-yr period of analysis. A mean of 28.4 routes (SD = 18.8, range = 8–62) were completed each year, and a mean of 18.3 (SD = 13.9, range = 3–66) Burrowing Owls were counted each year.

A steady decline in mean number of owls per route occurred from 1968–72 (range = 10–12 routes/yr), followed by 12 yr of oscillating numbers (1972–84, range = 8–28 routes/yr; Fig. 2). From 1984–86 there was a large increase. However, in 1984 there were only eight routes surveyed and three owls observed, in 1985 eight routes and 11 owls, and in 1986 eight routes and 13 owls. The 1984–86 increase, then, must be interpreted with caution because so few routes were surveyed. However, between 1987–2000, the number of routes surveyed each year was ≥28 (mean number of routes/yr = 46.2, SD = 14.4, range = 28–62 routes/yr, N = 14 yr). Therefore, surveys during the years 1987–2000 should reflect Burrowing Owl numbers more accurately. It is in these years that

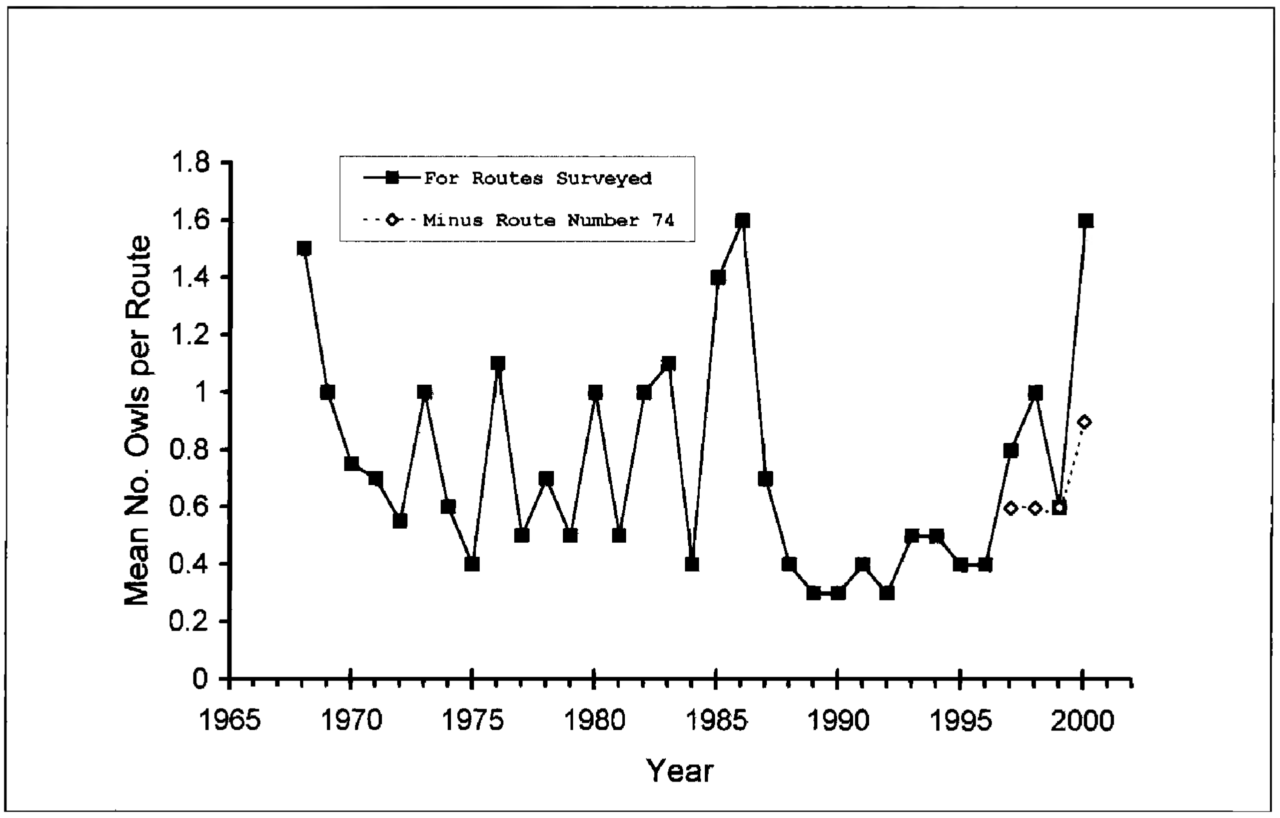

Figure 2. The mean number of Burrowing Owls per route in New Mexico, 1968–2000. Data from the North American Breeding Bird Survey.

owl numbers reached their lowest mean/route. Beginning in 1997, owl numbers showed an upward trend, culminating in 2000 with the highest (equal to 1986) mean number of owls/route. In 1997, route 74, a route that was first surveyed in 1992, reported an owl count that was 27% of that year's count; its 1998 count was 38% of the total; 1999's was 15%; and 2000's was 21%. Excluding counts from route 74, owl numbers leveled off from 1997–99, and then there was a modest increase in 2000 (Fig. 2). The factors responsible for route 74's high numbers from 1997–2000 compared to all other routes during those years are unknown.

Using the BBS results, we were able to identify specific areas (counties, locations, and routes) with the most Burrowing Owls. Six of the 10 counties with the highest numbers of owls are in the eastern part of the state, one is in the southwest, one in the northwest, one south-central, and one central (Table 4). All of these are in ecozones known to be used by Burrowing Owls (Fig. 1).

The central county, Valencia, with the highest total count, is south of Albuquerque in the Rio Grande valley. Irrigation ditches distribute water from the river to farmland. Plains-mesa sand scrub and desert grassland exist east and west of the val-

Table 4. Rank order of the ten highest county totals for Burrowing Owls (1968–2000), based on North American Breeding Bird Survey data.

COUNTY	LOCATION	BBS ROUTE NUMBERS	TOTAL OWLS REPORTED
Valencia	Central	15	89
Roosevelt	East-central	18, 74	83
Union	Northeast	6, 56, 62	50
Lea	Southeast	24, 30, 80, 130	40
DeBaca	East-central	17	39
Colfax	Northeast	5	38
Chaves	East-central/Southeast	23, 73	36
Luna	Southwest	25, 82	26
San Juan	Northwest	51	19
Dona Ana	South-central	77	12

ley farmland. BBS route 15 extends east-west across all three ecozones. It was surveyed each year from 1968–79; the 57 owls counted in this interval represent 42% of all owls reported in the state for those 12 yr. The route continued to be surveyed each year through 1997. Only three owls (out of 201 for the state), however, were reported in the 10 yr from 1988–97. Thus, a regularly-sampled route showed a marked decline beginning in 1988.

Similarly, route 6 in Union County reported stable owl numbers through 1986 and then no owls after 1991. Route 25 in Luna County had low owl numbers until an increase from 1983–91, but thereafter no owls were found.

In contrast, other routes (17, 18, 23) were sampled each year and had low to moderate numbers of owls throughout, without any striking changes. Routes 5 and 74 had no to low counts until 1992–93, then increased counts through to 2000. The remaining routes in Table 4 (24, 30, 51, 56, 62, 73, 77, 80, 82, 130) were often not surveyed until 1991–92 and then had low to moderate owl counts through 2000.

Burrowing Owls at Prairie Dog Re-establishment Sites. At the Ladder Ranch, Burrowing Owls had not been previously seen at the re-establishment sites and very few were reported anywhere on the ranch. By 1998, seven owl pairs were observed (J. Truett pers. comm.). In 2000, the two smaller prairie dog colonies (N = 11 adult prairie dogs each) each had two Burrowing Owl pairs, while the larger colony (N = 44 adult prairie dogs) had no Burrowing Owls (M. Wolf pers. comm.).

At the Armendaris Ranch in 2000, 24 Burrowing Owl pairs were found, 15 of which produced 53 fledglings (D. Berardelli pers. comm.).

Some Burrowing Owls at the Gray Ranch have been seen in the prairie dog colonies, but they also readily use kangaroo rat dens. Owls here have been termed "abundant," with no apparent declines or increases over the last 10 yr (B. Brown pers. comm.).

OTHER REPORTS AND SIGHTINGS

At the Jornada Experimental Range near Las Cruces, three pairs of Burrowing Owls were found in 2000 (D. Berardelli pers. comm.). There are no prairie dog colonies at this site, but there are rock squirrels and other mammals that provide burrows.

Hawks Aloft Inc. (unpubl. data) surveyed three BHP World Minerals mines in northern New Mexico for breeding raptors. One Burrowing Owl pair raised four young at the McKinley Mine, a surface coal mine on the Navajo Nation in northwestern New Mexico. Two other mines on the Navajo Nation were surveyed, both of which encompassed grassland areas with active prairie dog colonies. At the 3200 ha San Juan Mine, two Burrowing Owl pairs fledged a total of 10 young, but the fledging status of two other occupied burrows was unknown. The 13 000 ha Navajo Mine had four owl pairs that fledged a total of 12 young, but the number of fledglings was unknown at five other occupied burrows. Hawks Aloft Inc. also found two adults on a prairie dog colony at the Rio Grande Gorge in Taos County, north-central New Mexico.

To extend the study started at New Mexico State University, D. Berardelli (pers. comm.) is evaluating the nesting success of Burrowing Owls in urban areas of Las Cruces and Dona Ana County and in a native environment, the Armendaris Ranch. Berardelli and Arrowood found 35 pairs in Las Cruces in 2000; 24 pairs occurred at the Armendaris Ranch in 2000.

DISCUSSION

The continuing loss of prairie dogs is probably one of the most important factors influencing Burrowing Owl numbers in New Mexico. Around the turn of the century, Bailey (1932:123–124) observed extensive prairie dog colonies in southwestern New Mexico, particularly in Grant County. Bailey estimated that a third of Grant County was covered by prairie dog colonies, and using an estimate of 25 dogs/ha, he extrapolated that Grant County had 6.4 million prairie dogs. Such populations were almost certainly present in other parts of the state as well, particularly on the eastern plains. Burrowing Owls are currently finding and nesting in colonies where prairie dogs have been re-established, demonstrating the importance of these colonial sciurids for the owls. Rock squirrel colonies may substitute in part for prairie dog colonies, maintaining Burrowing Owls in some areas. Because Burrowing Owls and prairie dogs have shared an evolutionary history as a consequence of living together, it is not yet clear how the owls will fare in their association with rock squirrels.

Loss of habitat and burrows caused by increased development (i.e., conversion of arid lands to farmland, farmland to housing developments and commercial construction, the expansion of oil fields, etc.), must also affect Burrowing Owl populations. Decreased habitat quality and availability are, for example, reported to be major factors in the decline of Burrowing Owls in Canada (Zarn 1974, Wedgwood 1978, Haug and Oliphant 1990) and in California (McCaskie et al. 1979, Garrett and Dunn 1981). We receive numerous calls about owls in areas where construction is planned, but these represent a small proportion of the owls that are affected by development leading to loss of their burrows and offspring. However, Burrowing Owls are very adaptable; some have tolerated high levels of disturbance around their burrows (pers. observ.). Although relocations of nesting pairs have not been successful (C. Finley, C. Blood, P. Arrowood pers. observ.), pairs have sometimes been enticed away from construction areas by providing artificial burrows nearby (i.e., passive relocation; P. Arrowood, C. Blood pers. observ.). We have alerted city officials, planners, and landowners about the presence of owls so that nest burrows are not disturbed during the breeding season; we then worked with developers to provide owls other burrow sites to occupy once breeding was completed. There has been no overall loss of habitat or increase in disturbance at NMSU or Kirtland Air Force Base, yet owl numbers have declined in recent years at those sites.

The state of Chihuahua in Mexico has suffered severe droughts in recent years, forcing many residents to abandon their homes and farms. Although we do not know where the migrating owls of New Mexico spend the winter, Chihuahua is a candidate site for at least some of them. Thus, the drought conditions may affect winter survival and the number of owls that return to New Mexico. P. Arrowood (unpubl. data) has correlated the arrival of Burrowing Owls in Las Cruces with strong weather fronts coming out of the south, in the direction of Chihuahua. In Las Cruces, weather fronts coming from the west, southwest or southeast have not been associated with the arrival of owls. Owls that nest on the eastern plains may be overwintering in southern and/or western Texas where severe drought conditions have also occurred in some areas in recent years.

We know from our studies at NMSU, and at Holloman and Kirtland air force bases, that owls banded in a given year sometimes return the next year, and others go away for several years and then return. Some owls do not migrate but, instead, overwinter at the burrow they occupied in the previous summer. More males than females overwinter at NMSU (P. Arrowood unpubl. data). Additionally, observers at Holloman and Kirtland air force bases have not recorded any of the owls that were banded at NMSU, and vice versa. At all three sites, unbanded owls appear each spring. We do not know the movement patterns of the owls or how much site fidelity exists. With most of the urban and rural populations of owls in the Las Cruces area unbanded, many new owls could appear on the NMSU campus after having moved as little as 1–2 km. If the owls do display strong site fidelity and their site becomes uninhabitable, the stress of finding a new area could both delay breeding and affect the number of offspring they are able to raise

We have tried to pull together as many sources of information about Burrowing Owl numbers in New Mexico as we could locate. We have emphasized trends as opposed to absolute numbers. Based on a previous agency questionnaire, James and Espie (1997) reported New Mexico's population as stable, with 1000–10 000 Burrowing Owls, but those estimates were not derived from counts. The level of concern about the owl at this time is moderate but reflects the necessity to monitor the owls closely. This moderate concern is reinforced by the data we have summarized: some areas have experienced declines and some increases. Owls are moving into re-established colonies of prairie dogs in central New Mexico. Artificial burrows are being put in place where natural burrows have been lost and owls are using the artificial burrows. However, we do not know how many prairie dogs are being lost throughout the state, nor what conditions the owls experience where they overwinter.

ACKNOWLEDGMENTS

We would like to thank all those who took the time to participate in our questionnaire. Their efforts will help identify the future needs of the Burrowing Owl so that proper management goals can be established. We are also grateful to the scores of participants in the North American Breeding Bird Survey. Brad McKown and Ken Boykin provided Figure 1. Roy Arrowood and Ralph Campbell provided assistance. The Agricultural Experiment Station at NMSU provided further assistance. P.C. James, M. Rowe, T.I. Wellicome, and an anonymous reviewer provided valuable comments on the manuscript

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A POPULATION DECLINE RECORDED BY OPERATION BURROWING OWL IN SASKATCHEWAN

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ABSTRACT.—Operation Burrowing Owl (OBO) is a prairie stewardship program launched in Saskatchewan in 1987 to preserve Burrowing Owl (*Athene cunicularia*) habitat from cultivation. As of 2000, 459 OBO members were protecting 61 259 ha of grassland habitat. Of the sites protected, 97% (466) involved privately-owned land (21 376 ha) and the remaining sites were publicly owned (39 883 ha). Participants signed a voluntary agreement to report annually the number of owls on their land and to conserve the owls' nesting areas, even if sites became unoccupied. In recent years, the program has promoted conservation easements and assisted landowners with owl habitat enhancement. In recognition of participation, members received a gate sign, an annual newsletter, and educational material. In addition to conserving habitat, OBO has increased public awareness of the owl, participated in research, and monitored owl population changes. In 2000, 459 OBO members reported a total of 54 pairs, considerably fewer than the 681 pairs reported by 352 members in 1988. After correcting for non-responding members each year, the annual census indicated a 95% decline in estimated number of pairs over 13 yr from 1988 (1032 pairs) to 2000 (56 pairs); this represents an average decline of 21.5% per year. Between 1987–93, the mean number of sites with ≥5 pairs of owls was 26 (range = 10–42; 5–11% of sites). In contrast, by 2000, 94% of all formerly-occupied sites had zero owls, two sites had five pairs (<1% of sites), and no site had ≥5 pairs of owls.

KEY WORDS: *Burrowing Owl*; Athene cunicularia; *population decline*; *stewardship*; *endangered species*; *habitat conservation*; *Saskatchewan.*

Registro del declive de una población por la operación Búho Cavador en Saskatchewan

RESUMEN.—La Operación Búho Cavador (OBO) es un programa de manejo de praderas lanzado en Saskatchewan en 1987 para preservar el hábitat del Búho Cavador (*Athene cunicularia*) de la agricultura. Hasta el 2000, 459 miembros de la OBO estaban protegiendo 61 259 ha de hábitat de pastizal. De los sitios protegidos, 97% (466) involucraban terrenos de propiedad privada (21 376) y los sitios restantes eran de propiedad publica (39 883 ha). Los participantes firmaron un acuerdo voluntario para reportar anualmente el numero de búhos en sus tierras y conservar las áreas de anidación de los búhos, aun si los sitios quedaban desocupados. En años recientes, el programa ha promovido servidumbres para la conservación y ha asistido a los propietarios de las tierras mediante el mejoramiento del hábitat para los búhos. En reconocimiento a su participación, los miembros reciben un letrero en la puerta, un boletín de prensa anual, y material educativo. En adición a la conservación de hábitats, la OBO ha incrementado la conciencia publica hacia el búho, ha participado en investigación, y ha monitoreado los cambios en la población del búho. En el 2000, 459 miembros de la OBO reportaron un total de 54 parejas, considerablemente mas pocas que las 681 parejas reportadas por 352 miembros en 1988. Después de llamar la atención a los miembros que no responden cada año, el censo anual indicó un declive del 95% en el numero estimado de parejas en 13 años desde 1988 (1032 parejas) al 2000 (56 parejas);

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con una declinación promedio de 21.5% por año. Entre 1987–93, el numero medio de sitios con ≥5 parejas de búhos fue 26 (rango = 10–42; 5–11% de los sitios). En contraste, para el 2000, 94% de todos los sitios antiguamente ocupados no tenían búhos, dos sitios tenían cinco parejas (<1% de los sitios), y ningún sitio tenia ≥5 parejas de búhos.

[Traducción de Victor Vanegas y César Márquez]

The Burrowing Owl (*Athene cunicularia*) was classified as endangered in 1995 by the Committee on the Status of Endangered Wildlife in Canada (Wellicome and Haug 1995). Burrowing Owls nest in grassland plots ranging from <1 ha to vast tracts of prairie. Many of the owls are found in small tracts of land because most native-prairie habitat in Saskatchewan has been lost to cultivation. It is estimated that only 23% of natural terrestrial habitats remain in the Prairie Ecozone of Saskatchewan (James et al. 1999), and in many of the more arable municipalities, native prairie comprises <2% of the landscape (J. Moen publ. comm.). Accompanying the disappearance of grasslands are habitat fragmentation and changes in plant and animal species composition. Habitat loss, degradation, and fragmentation, and the associated low productivity and high mortality, have been identified as primary causes contributing to the Burrowing Owl's decline in Saskatchewan (e.g., Hjertaas et al. 1995, Wellicome and Haug 1995, Warnock and James 1997, Clayton and Schmutz 1999).

Because almost all arable land in Canada's prairie landscape is privately owned, conservation initiatives largely depend on, or are driven by, landowners. The need for public awareness and habitat protection was demonstrated in 1986, when a study in the Regina Plain (Hjertaas and Lyon 1987) found that suitable Burrowing Owl nesting habitat was vanishing rapidly, and owls were found on only 13 of 703 grassland plots searched. Operation Burrowing Owl (OBO) was launched in Saskatchewan in 1987, and in Alberta in 1989, to protect from cultivation those grassland parcels used by nesting Burrowing Owls. Although privately-held lands were initially targeted, participants now also include stewards of public lands, including provincial community and federal Prairie Farm Rehabilitation Administration (PFRA) pastures and urban centers. The initiation and first 7 yr of the OBO program was described by Hjertaas (1997). OBO has been delivered by Nature Saskatchewan (formerly Saskatchewan Natural History Society), with support from other agencies, since 1990.

The evolving objectives of the OBO program are to: (1) conserve prairie habitat where Burrowing Owls are currently nesting, or have previously nested, through voluntary habitat-protection agreements with landowners and public recognition of the role of landowners in conserving habitat; (2) promote conservation easements as a means of conserving native habitat in perpetuity (following passage of *The Conservation Easements Act* in Saskatchewan in 1997); (3) assist landowners with enhancement and restoration of Burrowing Owl habitat; (4) increase and maintain awareness of the Burrowing Owl as an endangered species, and at the same time increase awareness of the prairie ecosystem and the interrelationships of the species within that ecosystem; (5) annually census Burrowing Owls at OBO sites, and use this information to determine population trends; and (6) facilitate research in determining factors driving the population decline.

METHODS

Voluntary Agreements. The core of Operation Burrowing Owl continues to be a one-page voluntary agreement that OBO staff discuss and sign with landowners who have Burrowing Owls nesting on their property in the first year of contact (Hjertaas 1997). The OBO agreement is a "handshake agreement," not a legally binding agreement, and can be canceled by the member at any time. Participating landowners report annually the number of Burrowing Owls on their site and agree not to cultivate the described nesting area. The area of land in each agreement covers all or part of a quarter-section (65 ha), and landowners with owls on more than one location (quarter-section) sign an agreement for each location. One exception to this is that public lands have only one agreement for the entire area they enroll rather than for each quarter-section. All landowners are encouraged to continue to participate in OBO, even if owls do not return to breed, and thus to continue conserving habitat and reporting numbers (or absence) of owls. In recognition of their participation, landowners receive either a certificate or an OBO gate sign with their name (almost all request a sign). Participants are also sent educational material, including an annual newsletter about the Burrowing Owl, its status, and current research.

Initially, agreements were renewed after a period of 5 yr, but starting in 1994, agreements became indefinite, expiring only upon request. Landowners receive a 5-yr certificate of recognition after every 5 yr of participation

Conservation Extension. Since 1998, conservation easements with Nature Saskatchewan (NS) or Nature

Conservancy Canada (NCC) have been promoted to OBO members. Easements conserve prairie habitat in perpetuity by placing cultivation or development restrictions through legal agreements between NS or NCC and an owner of ecologically-significant land. Each landowner is eligible for a tax benefit for his/her donation equal to the change in land value caused by the easement.

In 1999–2001, OBO members were invited to apply for incentives to enhance and to restore Burrowing Owl habitat on their land. This program helps approved landowners convert cultivated land back to grassland by purchasing seed mixtures for native or tame grass (excluding crested wheatgrass [*Agropyron cristatum*] and smooth bromegrass [*Bromus inermis*], two highly invasive exotic species). In 2001, assistance with fencing and water development were also offered (in partnership with Saskatchewan Wetland Conservation Corporation) to protect native pasture through deferred grazing management. Land targeted for these programs is near sites that recently supported breeding Burrowing Owls and near existing pastures, especially in highly-fragmented areas.

Public Awareness. Since the initiation of OBO, the program has been widely promoted through annual newsletters, brochures, advertisements in rural newspapers, and presentations to schools, nature clubs, landowner meetings, and other groups. Articles on the Burrowing Owl and on OBO have appeared in the newsletters of other agencies, and media coverage has been solicited. Promotional tools have included owl-shaped refrigerator magnets, t-shirts, a poster, a portable display, youth and adult versions of slide shows, and fact sheets on *Operation Burrowing Owl and Conservation*, *Burrowing Owl Behavior and Biology*, and *Burrowing Owl Research*.

As an educational complement to the OBO program, the Saskatchewan Burrowing Owl Interpretive Centre (SBOIC) opened in Moose Jaw, in 1997, at a site that had Burrowing Owls nesting in the wild. The launch of the Centre was a joint initiative of the Moose Jaw Exhibition Company, Saskatchewan Environment and Resource Management, NS, and Wildlife Habitat Canada. In a small indoor facility, displays describe ongoing research and promote the role of the Burrowing Owl in the prairie ecosystem. The facility also contains a walk-in replica of a Burrowing Owl burrow, with giant eggs and a model owl that is 1.5 m tall. The Centre has two imprinted captive-bred owls that visitors can touch, and 12 other Burrowing Owls that can be observed in captivity. From a nearby permanent blind, visitors use spotting scopes to view wild owls at their nest burrows. The Centre now has year-round educational programming.

Burrowing Owl road signs, similar to other highway wildlife warning signs, alert drivers to exercise care along stretches of road with nearby nesting owls. Signs feature a black drawing of an owl, on a yellow background, with the words "Slow Down, Burrowing Owls, Next 2 km."

Annual Census. To determine the number of owls at each site, census cards were mailed to all OBO members every June. Reported owls and hectares enrolled in the program for a given year are based on members in the program as of 30 June of that year. To facilitate reporting, a toll-free "HOOT line" (1-800-667-HOOT) was introduced in 1991. In recent years, landowners were also asked if they were interested in receiving conservation easement information and roadside warning signs. In each year except 1996, almost all of the landowners who did not mail in their census card were contacted by phone for information.

In 1994, the OBO database was restructured and all OBO data entries were proofed against original records. Small discrepancies occurred between annual OBO summaries and the updated database. Because our results are based on this updated database, some of our numbers differ slightly from those reported by Hjertaas (1997)

Correction for Non-reporting OBO Members. Some members often failed to respond to our annual mail-outs requesting information on the number of owl pairs per OBO site. To estimate the total number of pairs per year on all OBO sites combined, we assumed that members from which we did not obtain owl counts (i.e., 'Unknowns') had the same mean number of owls per site as members from which we obtained counts (i.e., 'Knowns'). However, this assumption would be invalid if members who had no owls were less likely to respond to mail-outs than members who had owls. We therefore tested our assumption through follow-ups (phone calls or visits) to a large subset of the non-responding members each year from 1997–2000. This allowed us to compare the mean number of owls per member between 'Respondents' (those members who returned their census cards, e-mailed us, or phoned) and 'Follow-ups' (non-responding members who we later contacted). The mean (SE) number of owls per member, for Respondents vs. Follow-ups, was 0.20 (0.04) vs. 0.19 (0.04) in 1997, 0.21 (0.06) vs. 0.30 (0.06) in 1998, 0.21 (0.06) vs. 0.11 (0.03) in 1999, and 0.13 (0.05) vs. 0.10 (0.03) in 2000. The mean number of owls did not differ significantly between Respondents and Follow-ups (1997, $t = 0.12$, $P = 0.90$, df = 404; 1998, $t = -0.87$, $P = 0.38$, df = 412; 1999, $t = 1.52$, $P = 0.13$, df = 404; 2000, $t = 0.50$, $P = 0.62$, df = 380). Given these results, attributing the same number of pairs per member to non-responding Unknowns as to Knowns seems to be reasonable.

RESULTS AND DISCUSSION

OBO Membership. The OBO program began with 293 landowners in 1987, and grew steadily to 499 members by 1991 (Fig. 1). Membership in OBO remained fairly constant after 1991, fluctuating between 459 and 501 participants. Most members were private landowners (97% in 1998–99), and the remainder were stewards of public lands. Each year new landowners with owls joined the program, while others left the program, resulting in a relatively stable membership from one year to the next. New participants generally resulted from changes in owl distribution or through media efforts and recruitment efforts of the OBO coordinator.

Landowners leaving the OBO program usually did so because they wanted to cultivate formerly protected areas or they no longer owned the land. More recently, however, some landowners cited

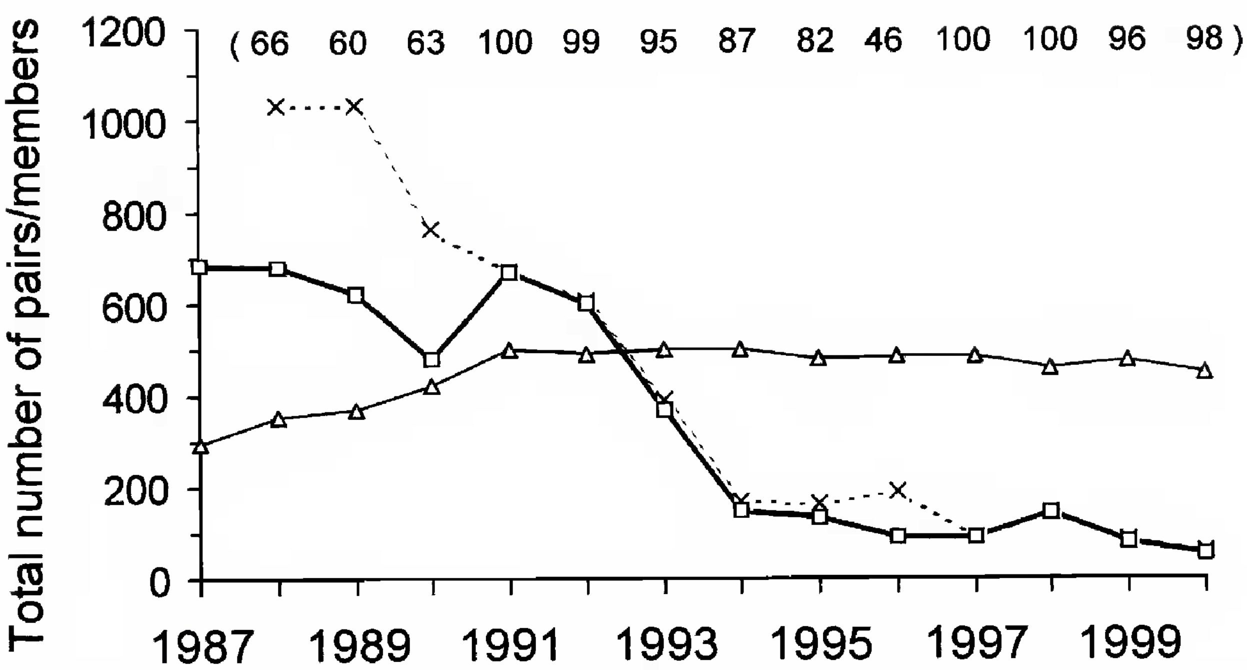

Figure 1. The total number of Operation Burrowing Owl (OBO) members in Saskatchewan between 1987–2000 (thin line). The thick line represents the number of Burrowing Owl pairs reported by participating OBO members ('Knowns' in methods section). By assuming that OBO members who did not report owl data ('Unknowns' in methods section) had the same mean number of pairs as members that reported data (Knowns), we estimated the total number of pairs that likely existed in each year (dashed line). Values in parentheses indicate the percent of all OBO members for which the number of breeding pairs was known each year.

concern about the Canadian Species at Risk legislation. Although not having owls for several years caused some landowners to leave the program, most continued to participate. Of the 675 individuals who joined the OBO program between 1987 and 1994, 504 (75%) of these were still enrolled 5 yr after joining, even though ca. 70% of them no longer had owls. In addition, members that remained in the program for 5 yr tended to remain to at least 1999 (<2% dropped out after 5 yr).

The proportion returning their OBO census cards varied from 1990 to 2000, and was lowest in the last 3 yr (36% in 1990, 33% in 1991, not applicable in 1992 [because all members were contacted directly], 60% in 1993, 55% in 1994, 52% in 1995, 34% in 1996, 58% in 1997, 20% in 1998, 21% in 1999, and 19% in 2000). Response via the toll-free HOOT-line (introduced in 1991) has remained low at about 2–4%. Providing postage-free OBO census cards, from 1991–95 (except 1992), did not improve the return rate of cards. It is possible that returns have decreased because members have learned that someone will phone if they do not mail in their census card.

Habitat Conservation. The total area enrolled by private landowners in the OBO program increased from 8962 ha in 1987 to 21 376 ha in 2000, a 139% increase over 13 yr. At public sites, 44 ha were enrolled in 1987, increasing to 39 883 ha in 2000 (the vast majority were in three PFRA pastures). The total area of private and public sites enrolled in 2000 was 61 259 ha. Of the area enrolled in 1987, 61% of that same area was still enrolled in 2000.

Between 1998–2000, >20 OBO members requested further information about conservation easements. In 2000, NS signed four conservation-easement agreements (one with an OBO member) conserving over 524 ha of grassland habitat. Four additional agreements are in negotiation, and NS referred 16 OBO landowners to NCC. In 2000, three landowners were approved for habitat-enhancement incentives, seeding a total of 178 ha of cropland to pasture.

Population Trend. Although the number of OBO members grew in the initial 4 yr of the OBO program and leveled-off thereafter, the known number of Burrowing Owls on OBO sites declined at an alarming rate (Fig. 1). In 2000, 459 OBO members reported a total of 54 pairs of owls, considerably fewer than the 681 pairs reported by the 352 members in 1988.

A correction for non-responding Unknowns is necessary to obtain a more accurate estimate of the total number of owls on all OBO sites each year. The total estimated number of pairs per year (Fig. 1) declined a dramatic 95% from 1988 (1032 pairs) to 2000 (56 pairs), a mean population decline of 21.5% per year. Mapping of pairs for 1987–2000

Table 1. Size distribution of Burrowing Owl 'colonies' at Operation Burrowing Owl sites in Saskatchewan from 1987–2000. Each value is expressed as a percent of the total sites for the year.

Year	Total Sites	No. of Pairs per Site							
		0	1	2	3	4	5	6–10	≥11
1987	418	—	61	21	7	4	3	3	
1988	378	19	37	22	11	3	2	4	1
1989	383	31	26	15	13	4	4	5	2
1990	343	41	29	13	6	3	3	3	1
1991	496	46	25	9	11	3	2	3	1
1992	488	53	23	11	4	4	2	2	1
1993	509	71	17	6	3	2	1	1	
1994	422	80	12	6	1	1			
1995	440	83	10	5	1				
1996	223	77	15	4	3			1	
1997	598	89	8	2		1			
1998	599	86	7	4	2	1		<1	
1999	610	92	5	2	1	<1			
2000	605	94	5	1	<1		<1		

indicates a disappearance of breeding owls over the entire Burrowing Owl's range within Saskatchewan (OBO unpubl. data).

Intensive field studies by researchers on the Regina Plain, Saskatchewan, corroborated the dramatic decline in the Burrowing Owl population through the 1980s and 1990s (James et al. 1997, Wellicome et al. 1997). When the percent annual decline estimated from OBO data (1991–99) was compared with the percent annual decline measured by biologists on the Regina Plain, no difference was found, supporting the reliability of the OBO data (paired t-test, $P = 0.66$; J. Hoyt and T. Wellicome unpubl. data).

Trend in Pairs per Site. Before 1993, sites with ≥5 pairs of owls were fairly common (5–11% of OBO sites); however, almost all sites since 1993 supported <5 pairs of owls (Table 1). Although at least 1% of sites had ≥11 pairs each year from 1988–92, no sites had that many pairs thereafter. In 1988, 1 yr after the OBO program started, 19% of sites had no owls, but many sites (43%) had >1 pair of owls. By comparison, in 2000 there were no Burrowing Owls at 94% of sites, and only a few sites (2%) had >1 pair of owls. New members (with owl pairs) join the OBO program each year, and their reports are included in annual owl totals. Sites occupied by one pair of owls seemed more likely to become unoccupied the following year (34%) than sites that originally had two (23%) or more pairs (6%).

Sources of Error. Rates of decline calculated from OBO data are approximate and are subject to inaccuracies such as miscounting, annual movement of owls, changes in number of sites being monitored from year to year, and changes in program delivery. Counts are likely accurate for sites with few owls (≤5 pairs), and prior to 1993 attempts were made to have biologists verify sites with >5 pairs (Hjertaas 1997). Because all sites are occupied when they are initially included in the OBO program, a decline might be expected over time even if the population was stable overall. Such an apparent decline might result from between-year movements of owls from OBO sites to previously unoccupied sites (Rich 1984, Hjertaas 1997). Some owls move to nearby sites and are not noticed or are not reported. This bias is at least partially offset by enrollment of landowners who report owls for the first time (Wellicome and Haug 1995).

Factors Contributing to the Decline. Factors that reduce habitat quality, decrease productivity, or increase mortality cause Burrowing Owl population declines (Wellicome and Haug 1995). In Saskatchewan, habitat change (loss, fragmentation, and degradation) appears to have adversely affected the population (James and Fox 1987, Wellicome and Haug 1995, James et al. 1997, Warnock and James 1997). Conversion of grassland to cropland in the last century resulted in the loss of over 75% of native prairie in Saskatchewan (James et al.

1999). In addition, habitat quality for Burrowing Owls has been reduced by fragmentation of large expanses of prairie, decreased prey availability, and a reduction in burrow providers (Wellicome and Haug 1995). Fragmentation likely results in greater predation pressure because of increases in edge habitats (Sugden and Beyersbergen 1986). Fragmented habitats may also affect dispersal and pairing success of the owls (Wellicome and Haug 1995, Todd 2001). Food shortage contributes to low survival of nestlings (Wellicome 1997, 2000), and possibly increases predation on juveniles and adults by reducing alternate prey for predators (Todd 2001). Other mortality factors include collision with vehicles (Todd 2001), and pesticides that suppress prey populations and directly affect Burrowing Owls (James and Fox 1987).

ACKNOWLEDGMENTS

Operation Burrowing Owl has been successful through the dedicated efforts of Saskatchewan Environment and Resource Management (SERM) staff (D.G. Hjertaas, W. Lyon, C. Palmer, and J. Pollock in the first year, and D.G. Hjertaas in the following two years) and Nature Saskatchewan staff (C. Bjorklund, D. Thornton, H. Dundas, C. Palaschuk, and P. Moore) in subsequent years. OBO has been supported financially by Canada Trust Friends of the Environment Foundation, Canadian Council for Human Resources in the Environment Industry, Canadian Wildlife Service of Environment Canada (EC), EcoAction 2000 and Action 21 (EC), Elsa Wild Animal Appeal of Canada, Endangered Species Recovery Fund (World Wildlife Fund and EC), Environmental Partners Fund (EC), Fish and Wildlife Development Fund (SERM), Human Resources Canada Summer Career Placements, Long Point Bird Observatory, Moose Jaw Exhibition Company, Mountain Equipment Co-op Environment Fund, Natural Legacy 2000 (Government of Canada Millennium Partnership Program), Nature Saskatchewan, Saskatchewan Partnerships Program, and Saskatchewan Wildlife Federation. We thank the dedicated summer students and many volunteers who have ensured the program's success, including the participating landowners and regional phoning volunteers. We appreciated the comments provided by T.I. Wellicome, R. Warnock, K. De Smet, J.K. Schmutz, and S.W. Hutchings on drafts of the manuscript. Thanks also to L.D. Todd, University of Regina, for sharing unpublished information, and to J. Moen, Saskatchewan Wetland Conservation Corporation, for providing a public communication on remnant native prairie in Saskatchewan.

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J Raptor Res. 35(4):378–384

DEVELOPMENT OF A HABITAT SUITABILITY INDEX MODEL FOR BURROWING OWLS IN THE EASTERN CANADIAN PRAIRIES

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ABSTRACT.—Recent efforts to sustain Burrowing Owl (*Athene cunicularia*) populations in Manitoba have been unsuccessful, and the species is now effectively extirpated from the province. Although specific causes of the decline remain unknown, loss, fragmentation, and degradation of suitable habitat have likely been major contributors to this decline. We developed a habitat suitability index model to determine suitability of Burrowing Owl nesting habitat in southwestern Manitoba and southeastern Saskatchewan. Model parameters were obtained using a modified Delphi technique to solicit expert opinions. An interactive, adaptive learning approach was used in model development, iteratively refining the model until acceptable levels of accuracy and robustness were achieved. Application of the model to historical Burrowing Owl breeding sites in Manitoba indicated that habitat suitability is often reduced by the presence of tall vegetation at former nest burrows. A management approach involving moderate grazing to maintain low vegetation height at all nest burrow sites is recommended.

KEY WORDS: *Burrowing Owl*; Athene cunicularia; *habitat*; *habitat suitability index*; *modeling*; *grazing*; *Manitoba.*

Desarrollo de un modelo de indice de aptitud del Hábitat para los Búhos Cavadores en las praderas orientales canadienses

RESUMEN.—Recientes esfuerzos por sostener las poblaciones del Búho Cavador (*Athene cunicularia*) en Manitoba no han tenido éxito, y la especie esta ahora efectivamente extirpada de la provincia. Aunque las causas especificas del declive permanecen sin conocerse, la perdida, fragmentación y degradación de la aptitud del hábitat han probablemente sido los mayores contribuidores a este declinación. Nosotros desarrollamos un índice de aptitud del hábitat para determinar la idoneidad del hábitat de anidación del Búho Cavador en el sudoeste de Manitoba y el sudeste de Saskatchewan. Los parámetros del modelo fueron obtenidos usando una técnica Delphi modificada para solicitar opiniones expertas. Un acercamiento interactivo, de aprendizaje adaptativo fue usado en el desarrollo del modelo, refinando iterativamente el modelo hasta lograr niveles aceptables de exactitud y robustez. La aplicación del modelo a sitios históricos de reproducción de Búhos Cavadores en Manitoba indicó que la aptitud del hábitat a menudo se reduce por la presencia de vegetación alta en las antiguas cuevas nido. Se recomienda un enfoque de manejo que involucre un pastoreo moderado para mantener la altura de la vegetación baja en los antiguos sitios de los nidos cueva.

[Traducción de Victor Vanegas y César Márquez]

Declines of Burrowing Owl (*Athene cunicularia*) populations in Canada (Haug and Oliphant 1990, James et al. 1997) have resulted in the species being designated as endangered (Wellicome and Haug 1995). Population declines have been accompanied by a contraction of the Canadian Burrowing Owl range, with the most pronounced range reduction occurring in the eastern Canadian prairies (Hjertaas 1997). Recently in Manitoba, the species has become effectively extirpated (De Smet 1997, Rothfels et al. 1999). Although many factors

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could be responsible for these changes, reductions in the quality and availability of grassland habitat are believed to be the major factors that have impacted Burrowing Owl populations (Zarn 1974, Haug and Oliphant 1990, Millsap and Bear 1997).

Because wildlife-habitat modeling often facilitates an improved understanding of the impacts of habitat alterations on wildlife populations (Morrison et al. 1998), we developed a habitat suitability index (HSI) model for Burrowing Owl populations in their former range of southwestern Manitoba. Habitat suitability index modeling was originally developed by the U.S. Fish and Wildlife Service (1981) as part of their Habitat Evaluation Procedures. HSI models evaluate habitat in relation to environmental factors that are deemed most important in influencing the presence, distribution, and abundance of a given species (Morrison et al. 1998). Such models can provide a repeatable assessment procedure for identifying changes in habitat suitability over time (U.S. Fish and Wildlife Service 1981, Schamberger and O'Neil 1986, Morrison et al. 1998). Our objective was to develop an HSI model that could be used to determine whether grasslands of southwestern Manitoba provide the habitat conditions required to sustain Burrowing Owl populations.

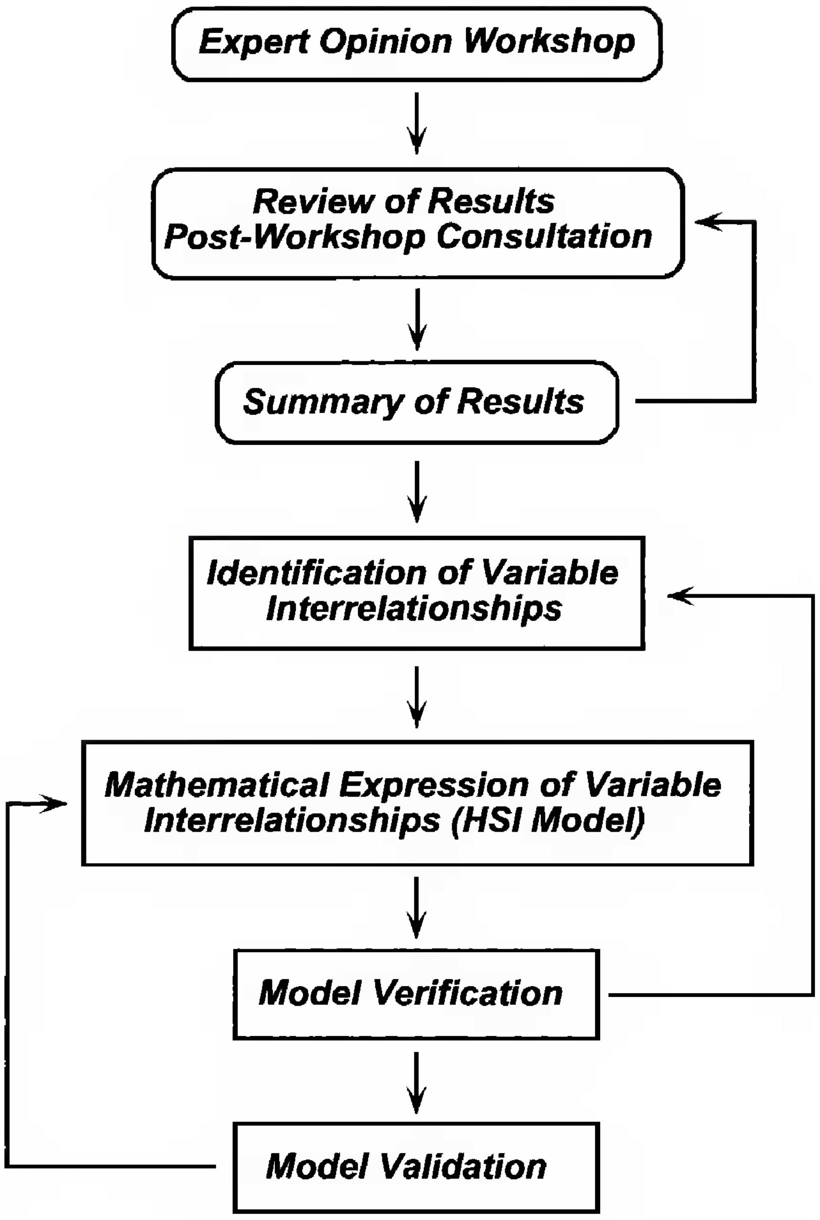

Figure 1. Flow diagram summarizing the development of the Burrowing Owl Habitat Suitability Index (HSI) model. Curved boxes represent the Delphi expert workshop stage, rectangles the numerical model development stage.

Methods

Modified Delphi Data Collection. Little information has been published on the site-specific, qualitative habitat requirements of Burrowing Owls in the eastern Canadian prairies. To obtain this information, we used a modification of the Delphi technique (Dalkey 1969, Crance 1987) to solicit opinions from regional Burrowing Owl researchers (Crance 1987). The Delphi technique originally used anonymous questionnaires to obtain information from experts and facilitate consensus building, but was subsequently modified to include group discussions among experts (Crance 1987). For the purpose of this study, the Delphi technique incorporated both a group discussion and a questionnaire component.

Five researchers, who had conducted studies on Burrowing Owls in southwestern Manitoba and southeastern Saskatchewan, participated in a workshop on 13 June 1997 in Regina, Saskatchewan. The workshop began with an overview of HSI models and the principles driving their development. Participants were then asked to identify nesting and foraging habitat requirements of Burrowing Owls in southwestern Manitoba and southeastern Saskatchewan based on their research experiences. As each habitat requirement was identified, participants collectively developed a suitability-index (SI) curve displaying the relationship between the habitat variable and the index of suitability. Participants considered each of the identified habitat components, and used a secret ballot voting method to select 10 components they believed were most important in determining Burrowing Owl habitat suitability. Votes were displayed and workshop participants then collectively modified these results as required to achieve group consensus.

Participants were then asked to consider interrelationships among the 10 habitat components as they related to Burrowing Owl habitat suitability and reproductive success. Individually, participants ranked each component by considering its importance for suitability of Burrowing Owl habitat. In addition, participants were asked to assign relative weights (scaled from 0.0–1.0) to habitat components, resulting in a mathematical description of the interrelationships functioning within the habitat. Equal ranking and weightings among two or more variables were permitted. Results of this secret ballot were subsequently displayed. Participants then reviewed and critiqued the component rankings and weights until consensus was reached.

Results of the workshop were later summarized and mailed to the participants for comments (Fig. 1). Participants were asked to approve or modify the results and provide clarification where necessary. Comments and suggestions from this questionnaire were incorporated into the workshop results and again forwarded to participants for their final approval.

Field Data Collection. To examine present-day habitat suitability of historical Burrowing Owl nest sites in southwestern Manitoba, fieldwork was undertaken in the vicinity of Melita (49°10'N, 101°00'W) within the mixed-grass prairie ecoregion of Manitoba (Scott 1996). In early-June 1998, proximate habitat was examined at 13 historical nest sites used by Burrowing Owls between 1987–97. Records of fledging success between 1987–97 (De Smet 1997, K. De Smet unpubl. data) were used to classify historical nest sites as successful (70% of broods fledged), marginally successful (30–50% of broods fledged), or unsuccessful (0 broods fledged). Of the 13 sites, six were classified as successful, two as marginally successful, and five as unsuccessful. The historical nest sites were located in present-day cattle pastures subjected to a variety of grazing intensities. Sites were interspersed among cereal and forage crops, haylands, summer fallow, and other grassland habitat types.

Because most Burrowing Owl activity occurs in habitats located ≤600 m of the nest burrow (Haug and Oliphant 1990), this study assessed habitat located within a 600-m radius of each nest site. Nest and forage vegetation heights, burrow availability, topography, perch availability, and openness were assessed at each nest site.

We assumed that Burrowing Owls select forage habitats consistent with optimum-foraging theory (Stephens and Krebs 1986). Therefore, potential Burrowing Owl forage habitat was examined within 600 m of the nest site using information provided by the workshop participants. Vegetation structure and composition were visually assessed by looking outward while walking a 50-m radius circle centered on the nest site. Roadside habitat within 600 m of the nest site was also assessed visually using information provided by workshop participants. Each distinct habitat was classified and assigned a suitability index (SI) based upon the workshop rankings. The areal extent of each habitat class was also estimated. Vegetation sampling was then undertaken, beginning with forage habitat having the highest SI and proceeding to habitats having lower SI values until a total forage habitat area of 9 ha or more was achieved for each nest site. Within each habitat type, vegetation height was measured at 10-m intervals along three randomly-positioned, 100-m transects, and mean forage vegetation height was calculated.

Nesting activity of Burrowing Owls is restricted primarily to habitat located within 50 m of the nest burrow (Haug and Oliphant 1990). To identify habitat suitability within this area, vegetation height was measured in each of the four cardinal directions 1 m from the nest, and also at 10-m intervals along a circle with a 10-m radius centered on the nest burrow. At all sample locations, height of vegetation was recorded to within 1 cm by using a meter stick.

Burrowing Owls on the Canadian prairies rarely excavate their own nesting burrows (Haug et al. 1993), relying instead on abandoned badger (*Taxidea taxus*) and Richardson's ground squirrel (*Spermophilus richardsonii*) burrows (Wellicome and Haug 1995). Participants of the modified Delphi process indicated that Burrowing Owls typically use holes having an entrance diameter of 8–35 cm. To determine burrow availability at each site, the number of natural and artificial burrows with entrance diameters of 8–35 cm were counted within a 10 × 10 m random plot located between 10–50 m from the nest burrow. In addition, perch availability and habitat openness were determined at each nest site by counting the number of perches and trees, respectively, within a 50-m radius of the nest. Site topography was assessed visually using incremental rankings from flat to moderately rolling.

Model Development. Information obtained from the modified Delphi process was used to develop an HSI model. To ensure that the identified habitat components were appropriate indicators of habitat suitability, the HSI compatibility of each variable was assessed using criteria developed by Schamberger and O'Neil (1986). In addition, the SI curves generated by the Delphi process were fitted to mathematical functions using regression analysis and statistical modeling (Jeffers 1982).

Model construction. Construction of the HSI model began by formulating model objectives and assumptions Variables considered to be inappropriate to the modeling objectives were excluded from consideration. Exploratory data analysis was used to summarize interrelationships among the remaining variables, and variables were each identified as limiting, cumulative, or compensatory factors using guidelines established by the U.S. Fish and Wildlife Service (1981). A mathematical expression of habitat suitability was generated (Fig. 1) using an adaptive learning process of combining habitat variables. Both arithmetic and geometric means of variables were considered in formulating habitat suitability. A multiplicative application was considered appropriate for limiting variables, as it ensured that the HSI would equal zero should any of the variable SI values equal zero. Cumulative variables were incorporated into the model additively, while compensatory variables were incorporated using either an arithmetic or geometric mean as deemed appropriate, recognizing that geometric means were more sensitive to individual low SI values than were arithmetic means. Variable weights identified by workshop participants were applied to compensatory variables to express their relative importance in identifying suitable habitat (U.S. Fish and Wildlife Service 1981).

Model verification. An interactive computer program was developed to verify the function, accuracy, and robustness of the HSI model (Fig. 1). Empirical habitat measurements were entered into the program to explore the multi-variable behavior of the HSI model, and to ensure that the computed HSI values reflected expert opinion. If the model behavior was deemed suboptimal, refinements were made iteratively until acceptable levels of accuracy and robustness were achieved.

Model validation. The HSI model was validated using field data from known Burrowing Owl habitat at Moose Jaw, Saskatchewan, and from historical Burrowing Owl habitat in southwestern Manitoba (Fig. 1). The Saskatchewan data were used to confirm that the model produced high HSI values for currently occupied habitat, while the Manitoba data were used to assess the suitability of historical Burrowing Owl nest sites for future populations

Table 1. Primary habitat variables, variable priorities, and variable importance weights (range of possible weights: 0.0–1.0), as determined by habitat-modeling workshop participants.

PRIORITY	PRIMARY HABITAT VARIABLE	IMPORTANCE WEIGHT
1	Burrow availability	1.0
2	Forage availability	1.0
3	Vegetation at nest site	0.8
4	Openness	0.8
5	Habitat fragmentation	0.7
6	Forage habitat quality	0.9
7	Inter-nest distance	0.5
8	Areal extent of nest pasture	0.2
9	Topography of nest area	0.2
10	Perch availability	0.2

RESULTS

Model Construction. Workshop participants individually identified 19 habitat components thought to affect the suitability of Burrowing Owl breeding habitat in the eastern Canadian prairies. Participants then reduced this to 10 components thought to be the most important in determining Burrowing Owl habitat suitability (Table 1).

Nine of the 10 habitat components identified by workshop participants were specific to habitat proximate (<50 m) to nest burrows, while the tenth addressed landscape-level habitat fragmentation. Given that the objective of this study was to develop an HSI model for small-scale, proximate habitat, the fragmentation measure was excluded. The remaining nine habitat components were redefined as variables for the purpose of model construction.

The contribution of the nine remaining variables to the HSI model was determined by considering the variable interrelationships identified by workshop participants. Number of burrows was deemed to be a limiting factor in identifying suitable nesting habitat because Burrowing Owls rarely excavate their own burrow. Because species survival is dependent upon the availability of suitable prey habitat, the quality and availability of foraging habitat were also deemed limiting factors. Inter-nest distance, openness and vegetation height at the nest burrow were identified as compensatory factors because high suitability levels for these variables were expected to offset low suitability levels of other variables. Topography at the nest site, areal extent of nest pasture, and perch availability were considered to have minimal influence on site suitability individually, but collectively, these variables were determined to be important. Topography at the nest site, areal extent of nest pasture, and perch availability were therefore considered to be cumulative factors.

An initial model was produced that included all nine variables in a weighted geometric mean, using the variable weights suggested by the workshop participants. The resulting model proved cumbersome and was insensitive to changes in variable values. To improve model function, the three variables weighted lowest by workshop participants were removed. Two additional variables were incorporated indirectly into the model as stipulations guiding model application. Specifically, the HSI was automatically set to zero under either of the following conditions:

(1) Openness: tree or tall shrub encroachment within 50 m of the nest site.
(2) Forage availability: no forage habitat located within 600 m of the nest site.

Subsequent model construction and verification focused on the four remaining variables.

HSI models are intended to be general indicators of habitat suitability that are easily and repeatably applied under field conditions. Minimizing the number of variables in the HSI model served two purposes: the model became more easily applied, and the likelihood of model overfitting was reduced (Jeffers 1982).

Model Verification. Model verification was undertaken by creating an interactive computer program to determine individual variable SI values and a composite HSI value for a specific set of habitat parameters. Approximately 500 sets of habitat parameters were generated to explore the utility and robustness of the model. An iterative process was used to modify model parameters until a suitable model was achieved. The final model took the form:

$$HSI = [(S_1)(S_2)(S_3^{0.8})(S_4^{0.5})]^{1/3.3}$$

where S_{1-4} are SI values for the following habitat variables:

S_1 = burrow availability
S_2 = forage vegetation height
S_3 = nest vegetation height
S_4 = inter-nest distance

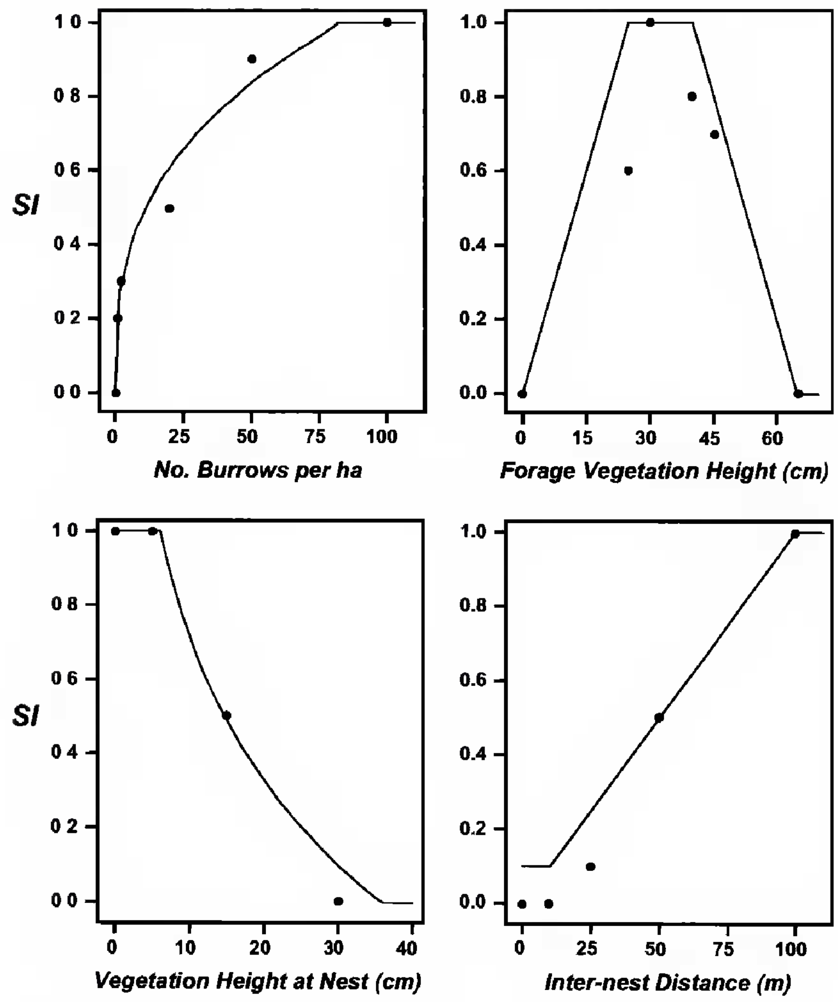

Figure 2. Suitability Index (SI) curves for the four habitat variables used in the Habitat Suitability Index (HSI) model. Fitted curves (solid lines) and variable values from the Delphi workshop participants (circles) are shown.

Variable weights incorporated into the model are provided in Table 1, and suitability index values for the four variables are presented graphically in Fig. 2.

A simpler model, excluding inter-nest distance, was developed for nest sites where Burrowing Owls were not present:

$$HSI = [(S_1)(S_2)(S_3^{0.8})]^{1/2.8}$$

Model Validation. Burrowing Owls have nested successfully in Moose Jaw, Saskatchewan for a number of years (E. Wiltse pers. comm.). The suitability of breeding habitat was assessed at nest sites located within two distinct study areas, the track infield of the Moose Jaw Exhibition Grounds and on land adjacent to the Lynbrook Golf Course. Eight nest sites were examined at the Moose Jaw Exhibition Grounds study area while an additional eight nest sites were assessed on the Lynbrook study area. Burrowing Owls were nesting on both study areas when the assessment was conducted. The HSI values for each of the study areas equaled 1.0, indicating that the model successfully recognized habitat that was being used by Burrowing Owls.

Of the 13 historical Manitoba nest sites examined, nine artificial nest burrows and four natural nest burrows were used. All historical nest sites were located on pastures that varied in the frequency and intensity of cattle grazing. Four historical sites were being grazed during the sampling period, while four others had remained ungrazed for a number of years. At the remaining five sites, grazing had occurred in the recent past, although historical grazing regimes were based solely upon supposition. Discussions with landowners indicated that these pastures were being subjected to rotational grazing practices at the time sampling occurred. Although other forms of habitat management can be used to suppress vegetation height (e.g., mowing, prescribed burning), only grazed sites were available for this study.

Individual SI values were determined at each of the Manitoba nest sites for three variables: burrow availability, vegetation height at the nest, and forage vegetation height. Inter-nest distance was not included because the sites were not occupied by Burrowing Owls when sampling occurred. SI values for burrow availability were >0.8 for 11 of the 13 sites, but two sites had low SI values (<0.5) due to a shortage of available burrows. Forage vegetation height SI values were all >0.8, and in 10 of the 13 historical nest sites maximum suitability values of 1.0 were achieved. SI values for vegetation height at the nest showed the greatest variation, ranging from 0.19 to 1.0. Together, these results indicate that forage habitat quality and burrow availability were close to maximum at most sites. By contrast, SI values for vegetation height at nest sites were often low, particularly in ungrazed pastures.

HSI values for the 13 sites ranged from 0.58 to 1.0, and were correlated with historical nest site success ($r^2 = 0.33$, $P < 0.05$; Fig. 3). HSI values of unsuccessful historical sites ranged from 0.58 to 0.79, with highest values occurring in pastures grazed when sampling occurred. By contrast, HSI values for successful historical sites ranged from 0.7 to 1.0, with smallest values occurring in sites that had not been grazed for some time. These results suggest that moderate cattle grazing of nest sites may be critical to the maintenance of suitable Burrowing Owl breeding habitat in southwestern Manitoba.

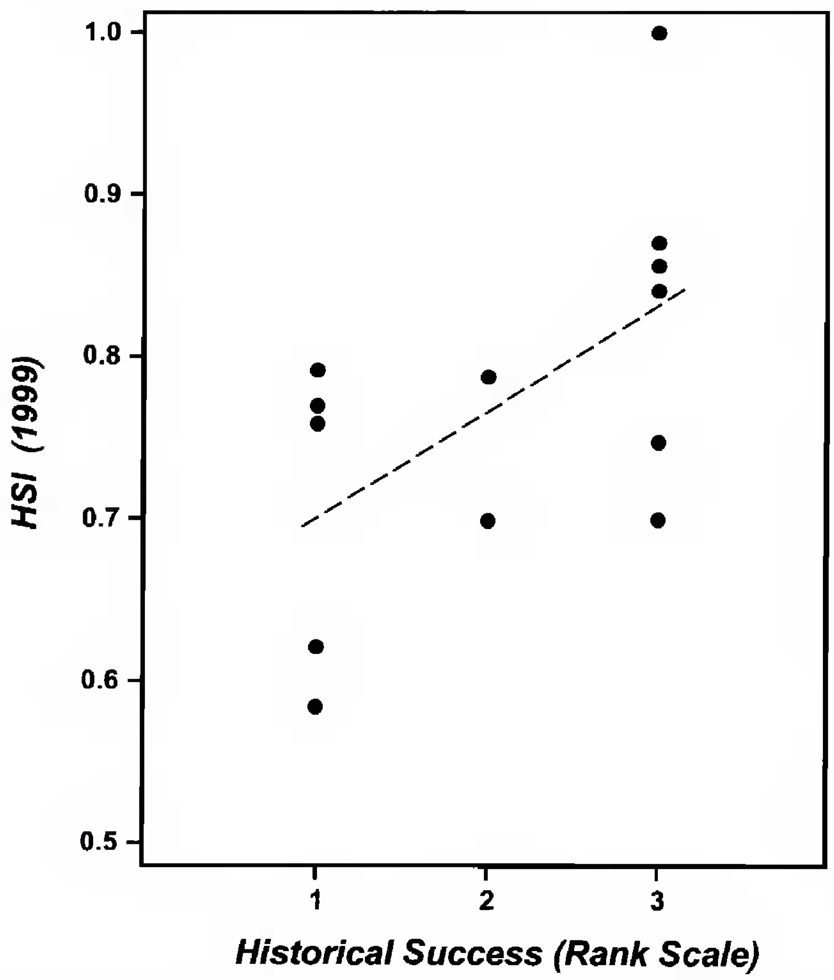

Figure 3. The relationship between brood-rearing success (1987–97) and Habitat Suitability Index (HSI) values (June 1999) for 13 historical Burrowing Owl breeding sites in southwestern Manitoba. Success codes are 1 = unsuccessful, 2 = moderately successful, and 3 = successful. The dashed line was fitted using linear regression.

DISCUSSION

The HSI model developed in this study incorporated directly four habitat variables considered critical in evaluating the suitability of Burrowing Owl habitat in southwestern Manitoba. An additional two variables were incorporated indirectly as stipulations guiding model application. During the early model development phase up to nine habitat variables were included; however, these more complex models proved to be cumbersome and produced unstable results. Similar results were obtained by O'Neil et al. (1988). Simpler models have the advantages of being tractable mathematically and easily applied under field conditions.

Application of the HSI model to historical Burrowing Owl nest sites in Manitoba suggested that habitat suitability was most strongly compromised by the presence of tall vegetation at the nest burrow. In southwestern Manitoba, native mixed-grass prairie and tame grasses may exceed 10 cm in height by early-June, particularly in wet years. By contrast, vegetation height in the drier mixed-grass prairies of southwestern Saskatchewan rarely exceeds 5–10 cm, even in the absence of grazing. In the Canadian prairies, annual precipitation increases from west to east and results in taller grass and forb species in southern Manitoba (Scott 1996).

In Manitoba, moderate grazing appears to be critical to maintaining an optimal (≤6 cm) vegetation height at nest burrows. Historical nest sites subjected to cattle grazing during habitat sampling were identified as having greater habitat suitability than ungrazed sites, indicating that grazing may enhance the suitability of Burrowing Owl habitat. In historically successful breeding habitat, cessation of grazing resulted in degraded habitats consisting of tall and lush grasses. De Smet (1997) identified over 700 pastures in southwestern Manitoba as potentially suitable habitat for Burrowing Owls; however, the quality of these habitats has not been formally assessed. The HSI model developed in this study can be used to assess these pastures, and identify the variables that compromise habitat suitability.

Population declines in Manitoba have been attributed previously to vehicular mortality and recent inclement, wet spring weather (De Smet 1997). Based on our analysis, we suggest that habitat deterioration at historical nest sites may have contributed to the effective extirpation of Burrowing Owls from Manitoba. Vegetation management at historical nest sites, such as regular grazing or mowing and either mechanical or fire management directed toward the removal of encroaching woody plants, should be implemented to improve Burrowing Owl habitat by maintaining consistently low vegetation height at nest burrow sites.

ACKNOWLEDGMENTS

This research was funded by Manitoba Hydro, Manitoba Conservation, and the Manitoba Raptor Foundation. The authors are indebted to T.I. Wellicome, D G Hjertaas, P.C. James, K.D. De Smet, K. Clayton, M. Shoesmith, R. Bukowsky, C. Johnson, and J. O'Neil for their advice and assistance. Thanks to K.D. De Smet, of Manitoba Conservation, for providing unpublished data on historical fledging success and to E. Wiltse, of Saskatchewan Environment and Resources Management, for providing a personal communication. We also thank K.D. De Smet, L. Takats, and an anonymous reviewer for their helpful suggestions. This study and its field research could never have been accomplished without the assistance and encouragement of the adventurous and perseverant V. Uhmann.

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J Raptor Res. 35(4):385–391

BURROWING OWLS AND DEVELOPMENT: SHORT-DISTANCE NEST BURROW RELOCATION TO MINIMIZE CONSTRUCTION IMPACTS

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Abstract.—During June–July 1998, we used a combination of active and passive relocation to move five Burrowing Owl (*Athene cunicularia*) nests in artificial burrow systems (ABS) that faced destruction by development in southwestern Idaho. Regulatory agencies agreed that relocation of the nest burrows would allow construction to proceed and provide an opportunity to determine the efficacy of moving occupied Burrowing Owl nests as a mitigation technique. Relocated nests contained one to five nestlings, ranging in age from 27–45 d. ABS (plastic chamber and tunnel), wooden perches, and dependent young were relocated (active relocation) to adjacent areas that contained natural vegetation; adults were not moved but were expected to travel the short distances to new burrow locations on their own (passive relocation). Access to natural burrows near original nest locations was restricted where possible. Relocation distances averaged 153 m and ranged from 72–258 m. Because terrain was flat, new nest locations generally were within view of original burrow locations. Relocations were successful at two of five nests. For two other nests, both adults and young returned to the vicinity of the original nest and occupied natural burrows 1 d after relocation. Owls from the fifth nest were not detected following burrow relocation and presumably vacated the immediate vicinity of the construction.

Key Words: *Burrowing Owl;* Athene cunicularia; *nest relocation; artificial burrow system; active relocation; passive relocation; mitigation technique.*

Búhos Cavadores y desarrollo: redisposición de las cuevas nido a corta distancia papa minimizar los impactos de la construcción

Resumen.—Durante Junio–Julio 1998, usamos una combinación de reubicación activa y pasiva para mover 5 nidos de Búho Cavador (*Athene cunicularia*) a sistemas de cuevas artificiales (ABSs), estos nidos estaban a punto de ser destruidos por el desarrollo en el sudoeste de Idaho. Las agencias reguladoras estuvieron de acuerdo que la redisposición de los nidos cueva debería permitir proseguir la construcción y proveer una oportunidad para determinar la eficacia de mover nidos ocupados de Búho Cavador como una alternativa de mitigación. Los nidos reubicados contenían de uno a cinco polluelos, con edades entre 27–45 d. Los ABSs (cámara y túnel plásticos), perchas de madera, y los jóvenes nidícolas fueron reubicados (reubicación activa) a áreas adyacentes que contenían vegetación natural; los adultos no fueron movidos pero se esperaba que recorrieran por su propia cuenta las cortas distancias a los nuevos sitios de las cuevas (reubicación pasiva). El acceso a las cuevas naturales cerca de los sitios de los nidos originales fue restringido a donde quiera que fue posible. Las distancias a la reubicación promediaron 153 m en un rango de 72–258 m. Debido a que el terreno era plano, las nuevas ubicaciones de los nidos generalmente estaban a la vista desde los sitios de las cuevas originales. La reubicación fue exitosa en dos de los cinco nidos. Para los otros dos nidos, ambos adultos y el joven retornaron a la vecindad del nido original y ocuparon cuevas naturales 1 día después de la reubicación. No se detecto que los búhos del quinto nido siguieran la reubicación de la cueva y presumiblemente se dispersaron de la vecindad inmediata de la construcción.

[Traducción de Victor Vanegas y César Márquez]

Burrowing Owl (*Athene cunicularia*) populations are declining throughout much of their range in North America (De Smet 1997, James and Espie 1997, Sheffield 1997). Human disturbances, such as elimination of burrowing mammals, use of pesticides and herbicides, and conversion of grasslands to agricultural or urban areas, are factors contributing to the decline in Burrowing Owl num-

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bers (Zarn 1974, Haug et al. 1993). Anthropogenic habitat change is continually displacing owls, forcing them from previous seasons' nesting areas, reducing prey abundance and foraging areas, and potentially limiting opportunities for breeding. Although regulations protect the owls, situations where Burrowing Owls and land uses conflict continue to arise.

To minimize direct impacts resulting from habitat conversion for agriculture or development, mitigation efforts often attempt to provide Burrowing Owls with suitable habitat near areas scheduled for development. Once mitigation land is established near an impact area, owls are either evicted (i.e., passive relocation) or actively relocated (Trulio 1995, Feeney 1997). Passive relocation usually occurs in the nonbreeding season or immediately before the breeding season commences. Under this scenario, owls are excluded from available natural burrows in areas slated for development and are forced to seek alternate burrows in nearby habitat outside the areas directly affected by construction. Active relocation entails: 1) capturing owls and moving them to suitable habitat, which is generally well removed from the original site; and 2) releasing the owls at a new site, often after a period of acclimation in temporary aviaries. To replenish or reintroduce populations, Burrowing Owls also have been translocated into areas where suitable habitat remained but natural populations had declined or were extirpated (Martell 1990, Dyer 1991). Translocation projects require active capture and transport of adults and juveniles from breeding areas and then release in establishment sites.

The efficacy of these mitigation techniques (active relocation, passive relocation, and translocation) has varied. Most relocation projects resulted in fewer breeding pairs of Burrowing Owls at the mitigation site than at the original site, and translocation projects generally have failed to produce self-sustaining populations. Investigators attribute the limited success of management efforts to: 1) strong site tenacity exhibited by Burrowing Owls, and 2) potential risks associated with forcing owls to move into unfamiliar and perhaps less preferable habitats (Trulio 1995, Delevoryas 1997, Feeney 1997). Further research on methods of Burrowing Owl relocation and translocation may lead to an increase in the success of these techniques.

In this study, we examined the responses of Burrowing Owl families to short-distance nest burrow relocation. We predicted that nest-site fidelity would be overcome through parental responses to their offspring, thus eliminating the need to capture and relocate adults.

We conducted this research in response to the planned destruction of a 130-ha field, in which five pairs of Burrowing Owls nested in 1998. Each artificial burrow system (ABS) contained a pair of adults and their dependent fledglings, which were still closely associated with their nest burrow. Before young were ready to leave their natal area (i.e., flight skills improving, but still dependent on adults), the field became a borrow pit for construction of a wastewater treatment facility; ultimately, the site will function as an effluent field in which alfalfa and other cover crops are grown. To allow the project to proceed, state and federal regulatory agencies agreed that the situation offered an opportunity to examine the feasibility of relocation of Burrowing Owl nest burrows to minimize construction impacts. We decided that nest burrows would be relocated to the periphery of the construction project, into a buffer strip surrounding the field. Burrow relocations would allow construction to continue without costly delays that would result from waiting until the owls migrated from the construction area after the breeding season.

This study provides data on relocation of ABS occupied by Burrowing Owls to determine if passive adult and active fledgling relocation is a feasible mitigation technique to avoid or reduce direct impacts from construction or other anthropogenic pressures.

METHODS

Study Area. Five Burrowing Owl nests were located approximately 3 km south of Kuna, Ada County, which is 32 km southwest of Boise, Idaho and <23 km north of the Snake River Canyon. Topography was flat to rolling, and elevations ranged from 841–896 m. Rock outcrops and a few isolated buttes (e.g., Kuna Butte, elevation 896 m) exist in the region. Annual temperatures range from −20 to +45°C, and annual precipitation typically averages <20 cm (NOAA 1985).

The study area was once a typical shrub-steppe community dominated by big sagebrush (*Artemisia tridentata wyomingensis*, Hironaka et al. 1983). Range fires and other disturbances have converted much of the surrounding shrublands to exotic grasslands dominated by cheatgrass (*Bromus tectorum*) and tumble mustard (*Sisymbrium altissimum*). The area contained a few homes, several large dairy farms, paved and gravel roads, and irrigated agricultural fields that grew primarily alfalfa, mint, and sugar beets. Irrigated agricultural fields bordered the northern, eastern, and southern sides of the field that was scheduled for construction, and a two-lane highway bordered the field's western edge. Previously excavated badger (*Taxidea taxus*) burrows were abundant throughout the study area and served as nest and shelter sites for Burrowing Owls (King 1996, King and Belthoff 2001).

Fledgling Data. Before moving nest burrows, we estimated the age of juveniles based on feather growth (Landry 1979) and the estimated hatching date of the brood (±1 d, Smith 1999). For individual recognition in the field, each owl received one United States Geological Survey aluminum leg band and a unique combination of three plastic color bands (National Band and Tag Co., Newport, KY).

Nest Relocation. Each of the five nest burrows were in ABS deployed as part of another study (Smith 1999, Smith and Belthoff 2001) in 1997 (Nos. 1, 3, and 5) and in 1998 (Nos. 2 and 4). Therefore, active relocation of nests and juveniles was relatively simple when compared with moving nests from natural burrows. This project occurred during the latter part of the nesting cycle; thus, we expected adult owls to move the short distance from the original nest area to the relocation site (i.e., passive relocation). However, nest burrows and fledglings were physically moved (i.e., active relocation) to sites outside the impacted area.

All five nests were relocated to a buffer strip between 25 June–9 July 1998. The buffer strip was along the western and southern borders of the field, was approximately 25 m wide, and was the nearest habitat with natural vegetation suitable for ABS placement (Fig. 1). We selected new nest locations that were as close as possible to the original nest location in areas deemed to provide sufficient space and habitat for owls. New sites generally were no closer to neighboring nests than were original sites (except for Nos. 3 and 5; Table 1) and, in each case, new nest locations were within view of original nests. After site selection, we: 1) dug holes to place relocated ABS, 2) removed all fledglings from their nest chambers, 3) removed each ABS intact (i.e., the chamber and tunnel), 4) buried each ABS at the new location with the same orientation as the original burrows, and 5) returned juveniles to nest chambers. We also moved the wooden perches from the original sites to the new sites to lure adult owls, who used the perches for roosting. Each ABS was encircled with highly-visible flagging to reduce chances that construction personnel would inadvertently disturb the new sites. To determine the fate of each relocated nest, we monitored relocation areas (via spotting scope from a vehicle as far away as possible) each day after relocation for 2 wk, and at least three times/wk thereafter until the date that migration normally commenced.

Burrowing Owls exhibit strong site attachment behavior (Trulio 1995, Delevoryas 1997, Feeney 1997), so we were aware that some owls might return to their original nest locations after the nest burrow was removed. To minimize this possibility, we first placed Owl Exclusionary Devices (OED) at natural burrows near the original nest site. Each OED consisted of a 0.5-m section of perforated plastic drainage pipe and a piece of transparent Plexiglas® attached to a hinge at one end of the pipe. Once placed at the entrance to a natural burrow, OED allowed any owls that were underground to exit but prevented owls from taking up residence at such burrows. We also attempted to coordinate relocations such that original nest areas would be destroyed shortly after nest burrows were moved, thus reducing the likelihood that owls would return to original nest locations.

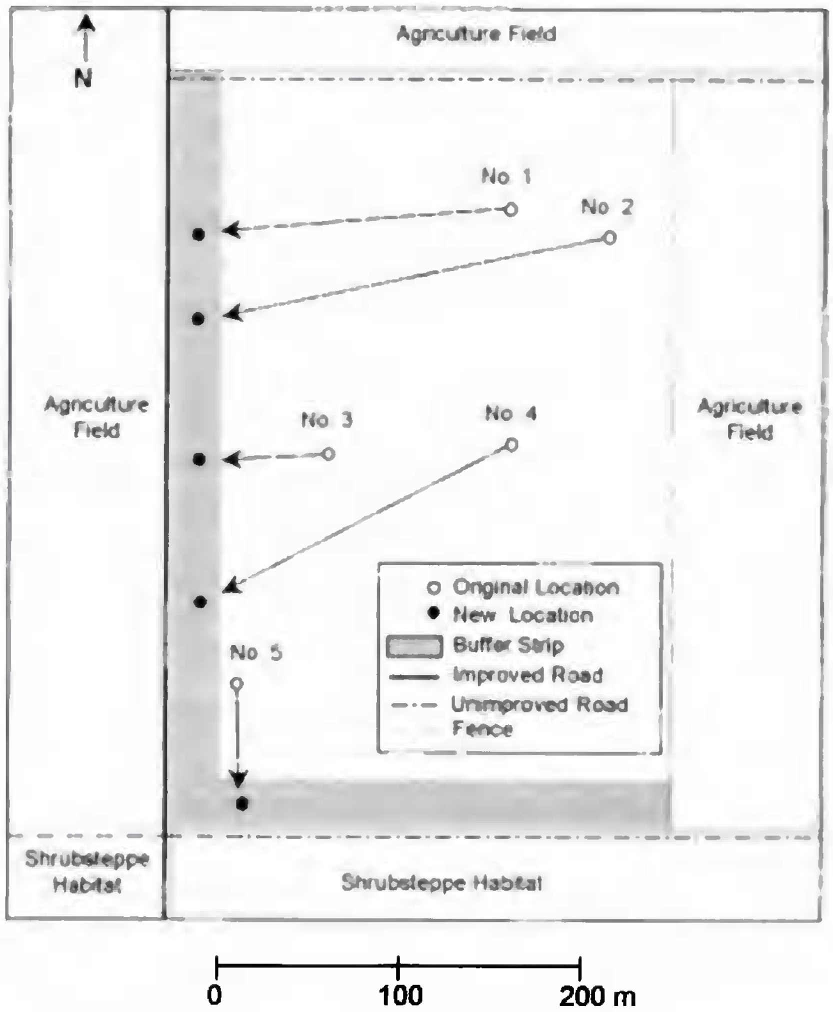

Figure 1. Original and new locations of artificial burrow systems relocated to minimize construction impacts on Burrowing Owl nests in southwestern Idaho, 1998. Numbers indicate nest burrows and their associated young that were relocated to a buffer strip along the western and southern border of the field; adults were not captured but were expected to locate the new sites on their own. The entire field (except the buffer strip) was leveled by machinery soon after all nests were relocated.

Upon relocating each ABS, we measured the distance (to nearest 0.5 m) and direction from the original nest location to its new site. We considered a relocation successful if the owl family took up residence at its new location and remained until dispersal or migration. Unsuccessful relocations occurred when owl families returned to their original nest areas or immediately disappeared from the study area; dispersal from natal areas at this young age is not characteristic of Burrowing Owls (King 1996, King and Belthoff 2001).

RESULTS

Fledgling Data. At the time of relocation, the number of juveniles at each ABS varied from one to five, ranging from 27–45 d post-hatch (Table 1). These young had developed modest to good flight capabilities, but they still depended on parental

Table 1. Information on Burrowing Owl young, relocation measurements, and apparent fates of relocated nests. Juveniles and artificial nest burrows were relocated during the 1998 breeding season to minimize construction impacts in Ada County, Idaho.

NEST	NUMBER OF YOUNG	AGE (d) OF YOUNG[a]	RELOCATION DATE	DISTANCE MOVED (m)	NEAREST NEST BEFORE (m)	NEAREST NEST AFTER (m)	FATE
No. 1	2	39–40	25 June	174	55	55	Accepted new site
No. 2	4	38–39	25 June	258	55	55	Site tenacity
No. 3	5	35–38	7 July	79	102	85	Disappeared
No 4	1	27	9 July	183	102	85	Site tenacity
No. 5	3	44–45	7 July	72.5	290	271	Accepted new site

[a] Estimated based on morphological development and estimated hatching dates. Young >28 d are considered fledglings.

care and remained associated with natal burrows. We captured and relocated all juveniles within each ABS except at No. 5 where, upon our approach to the nest, one fledgling flew ca. 25 m away. At No. 1, both young were captured and relocated, but immediately after being relocated one juvenile flew across the two-lane highway in the opposite direction of the original site.

Nest Relocation. Relocation distances averaged 153 m, ranging from 72.5–258 m, and four of the five nests were moved in a westerly direction (Table 1; Fig. 1). Overall, two families accepted their relocation sites (40%), two families (40%) returned to the vicinity of their original nest burrows, and one family (20%) disappeared from the field (Table 1). All family members from Nos. 1 and 5 were observed at their new sites 1 d after relocation, and both adults and fledglings from each family used their new sites for several weeks until they disappeared. In contrast, two families (Nos. 2 and 4) did not remain in the relocation areas. Instead, 1 d after relocation, family groups from these nests were observed at natural burrows <20 m away from their original nest burrows. The adult male from No. 4 began using the perch, and possibly the ABS, at the new site approximately 10 d after relocation, but his young and his mate remained near the original nest. Fates of birds from these nests are unknown, except for the female from No. 2 (see below). We believe family No. 3 moved from the immediate vicinity of both the original nest and the relocated burrow, even though this nest was moved only 79 m from the original site. After moving this ABS and all five fledglings, no members of the family were observed again at the original or relocation sites, or in nearby areas that contained suitable habitat for Burrowing Owls. The fates of the members of this family were also unknown, except for the male from No. 3 (see below). Finally, within the period of our study, dates of relocation events did not appear to be related to relocation outcomes (Table 1).

In 1999, two adults returned to the area and fledged young successfully from ABS that had been relocated to the buffer strip in 1998. The adult female that nested in No. 2 in 1998 (an unsuccessful relocation) nested at the relocated No. 2 ABS in 1999. The male that nested at No. 3 in 1998 (also an unsuccessful relocation) nested at the relocated No. 5 ABS. This represented a 20% return rate (by sex, and overall) for adults affected by construction in this field in 1998. During 1999, we observed none of the 15 fledglings from 1998 nests, despite continued work in the area.

DISCUSSION

Burrowing Owls typically remain within 50–100 m of their nest or satellite burrows during daylight hours (Haug and Oliphant 1990) and exhibit strong nest-site tenacity, even after a site has been disturbed (Zarn 1974, Feeney 1997). Because Burrowing Owls commonly use burrows in close proximity to their nest burrows for roosting, escape cover, and other activities (Zarn 1974, Haug et al. 1993), relocated nests should be in close proximity to the original nest burrow (Trulio 1995). For successful relocations in our study (Nos. 1 and 5), burrows were generally closer to their original sites than were those relocations considered unsuccessful (Nos. 2–4). However, three of five relocation distances were greater than the 100-m maximum distance that Trulio (1995, 1997) recommended for passive relocation techniques. Because shorter relocations generally were more successful, distance also may have been a relevant factor in the type of relocations we employed. However, as No. 3 family members were relocated only 79 m and apparently disappeared from the study area, other factors besides distance must play a role in relocation success.

Burrowing Owls commonly return to the same or nearby nest burrows year after year (Thomsen 1971, Rich 1984, Botelho and Arrowood 1998). For the relocations that we considered to be successful (Nos. 1 and 5), banding information from our study area showed that both adult males and one adult female bred successfully in the same field during the previous (1997) breeding season. Such experience could have made these owls more familiar with relocation areas and led to their increased willingness to accept new sites. For the three relocations we considered unsuccessful (Nos. 2–4), one adult male was known to have nested in this field during 1997, and the family dispersed from the field immediately following relocation. Ages and previous breeding experiences were unknown for the two remaining pairs, as these birds were not banded before they entered the 1998 breeding season. Nonetheless, familiarity with this field may have influenced whether a family accepted their relocation site, returned to the original nest area, or dispersed from the area.

Although immediate success was realized for two relocations, long-term success of relocations and their effects on Burrowing Owls are also important. In 1999, one female and one male returned to the buffer strip to nest (both had new mates). Of the two remaining ABS, one was occupied by a pair of unmarked owls and the other was unoccupied. The fifth ABS was destroyed during the nonbreeding season. Return rates for females on the impacted area were similar to female return rates over the entire area (20% vs. 24%, respectively) for 1997–98, but were lower for males on the impacted area than over the entire area (20% vs. 44%, respectively, J. Belthoff and B. Smith unpubl. data). We failed to detect any of the juveniles from this study in the impacted field or in surrounding areas during 1999. However, this is not surprising because only 15 juveniles were associated with this field, and first-year return rates are very low (<4% of banded individuals during 1997–98) for birds in our area (J. Belthoff and B. Smith unpubl. data). Nonetheless, the subsequent return and successful nesting of two adults to the impacted site in 1999 suggested that our methods provided both immediate and longer-term success for some of the owls involved.

Other factors also may have affected the owls' willingness to accept new sites. Unfamiliar disturbances (e.g., traffic) could have caused the owls to reject the new sites (Feeney 1997). Both Nos. 2 and 4 (unsuccessful relocations) were relocated from relatively quiet portions of the field to <25 m from a busy road (Fig. 1). Given surrounding land use and destruction of the field, the placement of each relocated nest was restricted to the buffer strip because it offered the nearest "suitable" habitat Also, we were unable to have the original nest areas destroyed immediately because of inclement weather (i.e., destruction of sections of the field did not occur on planned dates). These delays, or our inability to locate all natural burrows near original nest locations to place OED, potentially allowed two families (Nos. 2 and 4) to return to natural burrows near their original nest areas.

Finally, for the two successful relocations (Nos. 1 and 5), one juvenile from each nest either was not captured or escaped during the relocation process. At the time of relocation, juveniles from successful nests also were older than those from unsuccessful nests. It is not clear if or why these factors would affect the tendency for families to remain in the relocation area. Possibly, separation of family members led to increased rate of contact vocalizations by juveniles, which lured adults to the new site more readily, or the older individuals were more visible because of increased activity (i.e., practice flights, perching, hunting) around the relocation site.

Our results indicated that short-distance relocation of occupied nests was successful under some circumstances, although the factors associated with success remained unclear. Regardless, the relocations we performed avoided the almost certain death of many young owls that would have resulted from construction. Because this was a small study (five nests), success rates for the techniques described here should be quantified in much larger studies before such relocations are considered viable options. Additionally, whether the techniques we examined would relate also to owls nesting in natural burrows (the most likely situation faced in many areas) remains unknown. Currently, we recommend that these techniques be used only when no alternatives exist. Postponing mitigation and construction activities until the nonbreeding season (i.e., after dispersal and/or migration occurs), as well as compensating for any habitat loss or degradation, would be the preferred approach to reduce impacts on Burrowing Owls. If mitigation activities cannot be avoided, original nest areas should be destroyed immediately after moving the owls so they cannot return to the original burrow, or any other burrow, in the impacted area (Trulio 1995). Finally, it remains unknown whether actively relocating adults with their dependent young would affect success rates of short-distance relocations. If the stress of capture on owls is not severe, it seems reasonable that including adults would increase relocation success. However, it may be difficult to capture adults late in the nesting cycle, so timing of the relocation would be important. Therefore, passive relocation of adults and active relocation of fledglings may encourage adult Burrowing Owls to overcome nest-burrow tenacity and inhabit new burrows to care for young when relocations are over short distances.

ACKNOWLEDGMENTS

We thank L. Hannon and B. Nelson for assistance with fieldwork and the U.S. Fish and Wildlife Service and Idaho Fish and Game personnel for consultation on this project. Financial and logistical support for our research on Burrowing Owls has been provided through challenge cost share grants from the Bureau of Land Management to J. Belthoff, by the Department of Biology and Raptor Research Center at Boise State University, and by the Snake River Field Station, Forest and Rangeland Ecosystem Science Center, U.S. Geological Survey, Boise, Idaho. Finally, we thank E. Botelho, A. Dufty, D. Plumpton, S. Novak, L. Trulio, and T. Wellicome for comments on previous versions of the manuscript.

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J Raptor Res. 35(4):392–398

BURROWING OWL REINTRODUCTION EFFORTS IN THE THOMPSON-NICOLA REGION OF BRITISH COLUMBIA

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Abstract.—British Columbia (BC) designated the Burrowing Owl (*Athene cunicularia*) as endangered in 1980. In 1989, non-government organizations and local resource users, under the direction of the Ministry of the Environment, Lands, and Parks, launched a cooperative, captive-breeding and release program to restore Burrowing Owl populations in BC. The first phase of this program (1992–97) emphasized refining breeding protocols and identifying critical habitat features necessary for owl survival and reproduction in the wild. Successive releases provided insight into the feasibility of re-establishing populations to the grasslands of the Thompson-Nicola region. Results indicate that 1-yr-old, captive-bred owls are capable of: 1) surviving at release sites, 2) raising broods, 3) over-wintering at or near release sites, and 4) migrating south and sometimes returning to release sites the following spring. Given these general results, the potential for a successful reintroduction of Burrowing Owls in BC exists, provided that more owls are released, and key habitat is enhanced. The second phase will emphasize ecosystem restoration, taking into account historical changes in natural processes (i.e., fire, grazing, and the resulting impact on faunal and floral composition on grassland habitats). In the second phase, the number of released owls will be increased to 50 pairs/year.

Key Words: *Burrowing Owl*; Athene cunicularia; *captive breeding*; *reintroduction*; *grasslands*; *British Columbia.*

Esfuerzos de reintroduccion del Búho Cavador en la region de Thompson-Nicola, Colombia Británica

Resumen.—En Colombia Británica, el Búho Cavador (*Athene cunicularia*) se designó especie en peligro de extinción en 1980. En otras partes de el Canadá, esta designación le fue dada en 1995. En 1989 se estableció un programa bajo la dirección del ministerio del medio ambiente para re-establecer la población usando lechuzas criadas en cautiverio. La primera fase de este programa (1992–97) tuvo como propósito refinar la crianza de lechuzas, e identificar las particularidades del habitat que son criticos para la supervivencia y reprodución de dichas lechuzas. Las liberaciones consecutivas han proveido resultados que permiten evaluar la posibilidad de re-establecer poblaciones de lechuzas en praderas de la region de el Thompson-Nicola. Los resultados obtenidos sugieren que lechuzas criadas en cautiverio pueden: 1) sobrevivir en los lugares de liberación, 2) reproducirse, 3) hibernar en los lugares de liberación, y, 4) emigrar y retornar. Dados los resultados observados, pensamos que las posibilidades de reintroducir a esta especie es posible siempre y cuando se liberen mas lechuzas y se restaure la integridad de su habitat. La segunda fase tendrá como propósito restaurar la integridad del habitat tomando en cuenta disturbios naturales (asi como fuego y sus efectos a la fauna y flora de las praderas) e implementar liberaciones en grupos que consistan de no menos de 50 pares.

[Traducción de autores]

Burrowing Owls (*Athene cunicularia*) in British Columbia (BC) are at the northern extent of the interior Great Basin grassland system of Oregon, Washington, and south-central BC. Historically in BC, the owls were found most commonly in the grasslands of the Southern Interior, although the species' range may have stretched as far north as the Cariboo Chilcotin grasslands (R. Cannings unpubl. data). Historical accounts between the

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1960s–80s from ranchers in the area suggest that the Burrowing Owl was a regular and widespread breeding species in the early part of this century. However, decades of habitat alteration, through urban and agricultural development, incompatible grazing practices, eradication of fossorial mammals, and suppression of natural disturbance, resulted in the extirpation of the Burrowing Owl from BC (Howie 1980). The last reported breeding colony of Burrowing Owls disappeared in the mid-1960s from the Vernon Commonage, southwest of Vernon (Vernon Naturalist Club unpubl. data). Since then, sporadic reports of breeding Burrowing Owls have come from several areas within the Thompson-Nicola region. The last authenticated record was in August 1979 by W. Campbell, of the BC Royal Provincial Museum, who saw five Burrowing Owls southwest of Sabin Lake on Douglas Lake Ranch east of Merritt, BC, and a single bird at nearby Stoney Lake (R. Ritcey, D. Jury, and D. Low unpubl. data).

The Burrowing Owl was designated as an endangered species in BC in 1980. As a result of this listing, the Ministry of the Environment, Lands, and Parks (MoELP) launched a recovery program to restore the owl population in the province. Over a number of years between 1983–88, Burrowing Owls obtained from the Owl Rehabilitation and Research Foundation, Vineland, Ontario were released into the Thompson and Nicola valleys in an attempt at reintroduction (R. Ritcey, D. Jury, D. Low, D. Murphy unpubl. data). A subsequent attempt at reintroduction involved the translocation of Burrowing Owl families from the Moses Lake area in Washington to the South Okanagan (Dyer 1991). This project had limited success and monitoring efforts ceased in 1994 (O. Dyer pers. comm.). In view of these results, another attempt was initiated in 1989, but this time a captive breeding and reintroduction program was developed. This project's goal was to reintroduce Burrowing Owls into selected grassland habitats in three or more locations in the Thompson-Nicola region.

The Burrowing Owl captive-breeding and reintroduction project is a cooperative effort between government, private landowners, non-profit organizations, and a large body of volunteers. Because the amount of monitoring that could be done in a given year depended on funding, which varied among years, monitoring was not consistent among years and sites.

The first phase of the reintroduction project was aimed at refining breeding protocols and identifying factors that would improve the probability of successful reintroduction. Specifically, we examined mortality, diet, productivity, and migratory behavior of captive-bred and released birds and compared the results to those of wild populations.

METHODS

Breeding Facilities. There are two breeding facilities in BC. They are geographically separated from each other to reduce the risk of catastrophic loss of the limited gene pool. Both facilities were established and operated by private organizations. Construction of facilities was accomplished with government financial assistance, and corporate and private donations.

Kamloops Wildlife Park breeding centre. Constructed in 1989, the Kamloops Wildlife Park is the main breeding facility for the Burrowing Owl program. The wildlife park has space for 10 breeding pairs. A central sheltering building (5 m × 10 m) contains eight separated nesting burrows that lead into individual exterior flyways for paired birds. A common flyway (3 m × 33 m) surrounds the individual enclosures and can be used by all birds outside of the breeding season. Public viewing is restricted to one side of the building. In 1996, a new juvenile pen (8 m × 30 m) was constructed beside the breeding enclosure. The pen, which contains six nesting chambers, also serves as a second breeding facility.

San Rafael Aviaries breeding centre. From 1992–97, a small facility was maintained at Stanley Park in Vancouver, BC When park changes forced the removal of this enclosure, the new facility was constructed at San Rafael Aviaries, near White Rock, BC, with the support of the University of BC Animal Science Department. The breeding center consists of a large outdoor aviary (18 m × 18 m) that is divided into three sections to accommodate three breeding pairs. Two small buildings that adjoin the flight cage contain nesting burrows for each enclosure. These nesting burrows are connected to the outdoor flight pen by underground pipes. After the breeding season, partitions can be removed to allow communal use of the flyway space.

Release Sites. Releases were conducted in grassland systems within the Thompson/Nicola region, near the cities of Kamloops and Merritt (Fig. 1). Grasslands in BC range from 350–1250 m in elevation. Lower elevation grasslands (350–900 m) are characterized by low annual precipitation rates (range = 160–458 mm) and are dominated by big sagebrush (*Artemisia tridentata*), bluebunch wheatgrass (*Agropyron spicatum*), and needle-and-thread grass (*Stipa comata*). Higher elevation grasslands (900–1250 m) are characterized by higher precipitation rates (range = 376–512 mm) and are dominated by pasture sage (*Atemisia frigida*), rabbitbrush (*Chrysothamnus nauseosus*), rough fescue (*Festuca scabrella*), and introduced Kentucky bluegrass (*Poa pratensis*). A total of nine areas was used between 1992–97 (Fig. 1). Selection of specific release sites in the Thompson-Nicola region (Fig. 1) was based on several criteria: historical and current sightings of wild owls, grassland condition, quality of habitat for rodents, existing grazing regimes, land ownership, and long-term availability of habitat.

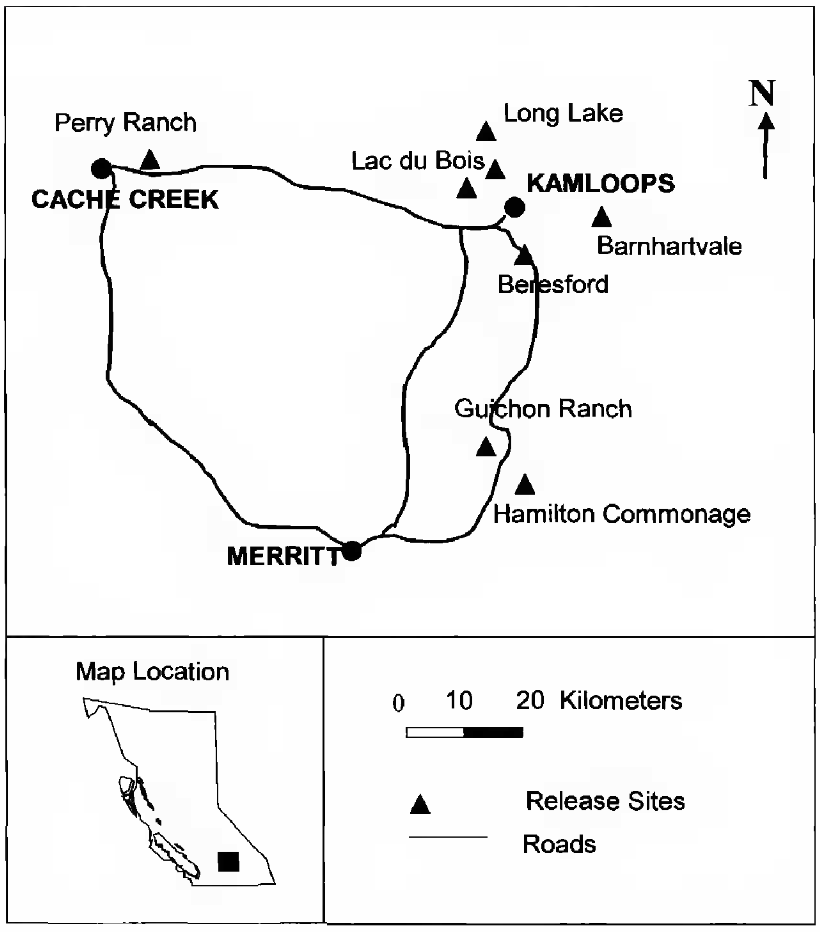

Figure 1. Burrowing Owl release sites in the Thompson-Nicola region of south-central British Columbia.

Releases. Owls were released as 10-mo-old birds (hereafter, 'yearlings'). Releases were conducted between April–June at pre-determined sites. Because burrow availability is a limiting factor in British Columbia (Howie 1980), artificial burrow networks were constructed at each release site. Each burrow network consisted of two to four burrows in upland areas, so owls could nest and avoid predators, and four to eight security burrows, placed 15–50 m apart near meadow vole (*Microtus pennsylvanicus*) habitat, for foraging males. Burrows were made of 15-cm diameter perforated flexible plastic pipe that was 2.0–2.8 m in length. Nesting burrows were a combination of three 11–19 L plastic buckets (two buckets placed bottom against bottom, with human-access holes through the bottoms, and the third bucket placed inside the upright bucket). The owls accessed the inverted bottom bucket nest chamber through a pipe leading to the base of the lower bucket.

Two months prior to releases, owls were segregated by gender to prevent premature breeding attempts. Standard blood DNA analyses for sexual identification were used to determine sex (Griffiths et al. 1988). One-week prior to release, owls were provided with live prey. Shortly before release, yearlings were fitted with United States Geological Survey bands and numbered color bands. Siblings were released at separate locations to minimize the potential for inbreeding. At release sites, owls were placed into artificial burrows. Burrow openings were blocked to allow owls to acclimate to their new burrows for up to an hour. Once or twice weekly for the first 4 wk after the release, day-old chicks were provided to all owls except those released in more remote areas, where feeding took place once every 2 wk.

Owl Monitoring (1993–97). Monitoring consisted of recording owl movements, site persistence, predation, and breeding success. Monitoring of released owls was conducted from the date of release until the departure of owls to wintering grounds. Monitoring intensity varied from site to site and among years. Areas close to the Kamloops center were monitored every second day, while those more than 80 km away from Kamloops were visited only once per week. In 1996, radio-telemetry transmitters (collar-style) were fitted on male owls to determine both the location of missing individuals and movement patterns during daily activities. Only males were fitted with radio-transmitters because females seldom move from the burrows during oviposition, incubation, and early-brooding.

Prey Consumption (1993–97). Prey consumption and seasonal shifts in prey availability were determined by examining regurgitated pellets. Pellets were collected primarily at burrow entrances, and were then air-dried and later dissected. The various taxa that made up each pellet were separated. Diet composition was expressed for each taxa in each pellet as the mass of dry remains of that taxa divided by the total mass of the pellet. Supplemental feed was occasionally found in pellets, but was excluded from the mass measurements. Diet composition was then separated into 3 periods: April–May (pair bonding and egg laying), June–July (incubation and fledging), and August–September (dispersal), and expressed as a percent

RESULTS

Releases. A total of 106 owls were released between 1992–97 at eight separate sites (Table 1). Selection of sites and the number of owls released at each site was guided primarily by the availability of releasable owls and previous success in a particular site. Sex ratios were close to the expected 50:50 ratio, although in 1995 the ratio was strongly skewed toward males.

Site Fidelity. Released yearlings showed high fidelity to release sites; once released, 95% of the owls remained at release sites. In most instances when birds did leave, we were unable to relocate them. However, one female bird moved 4 km from the original release site to a second release site. This movement occurred after all other birds at the first site were killed by predators. Owls often utilized structures other than the artificial burrows that we provided. Such structures included culverts, spaces under abandoned buildings, discarded tires, and, on one occasion, a natural burrow.

Mortality. Mortality of released yearlings was difficult to ascertain because many individuals disappeared. However, telemetry studies in 1996 (N = 6) and 1997 (N = 7) showed that 12 (92%) owls that disappeared from their release sites were killed by predators. Therefore, we assumed for previous years that all individuals that could not be

Table 1. Number of yearling owls (males/females) released at various sites each year.

Site	Date of Release						Total
	24 May 1992	27 Mar 1993	9 Apr 1994	25 Mar 1995	30 Mar 1996	18 Apr 1997	
Beresford	—	—	8 (4/4)	5 (3/2)	4 (2/2)	5 (3/2)	22
Lac du Bois	9 (?/?)	7 (?/?)	5 (3/2)	4 (4/0)	4 (2/2)	4 (3/1)	33
Long Lake	—	—	—	4 (3/1)	6 (3/3)	4 (2/2)	14
Perry Ranch	—	—	—	—	4 (2/2)	2 (1/1)	6
Guichon Ranch	—	—	5 (2/3)	5 (3/1)	3 (2/1)	3 (1/2)	16
Barnhartvale	—	4 (?/?)	—	—	—	—	4
Agriculture Canada	—	4 (?/?)	3 (2/1)	—	—	—	7
Hamilton Commonage	—	—	—	—	—	4 (2/2)	4
Total Number	9 (?/?)	15 (?/?)	21 (11/10)	18 (14/4)	21 (11/10)	22 (12/11)	106

located at their release site, or at adjacent release areas, were killed by predators. Using this assumption, mean mortality for all years combined was 34% (range = 10–54%). Eighty-five percent of mortalities occurred within the first 4 wk of release. Based on recovered carcasses, 14 deaths were caused by avian predators, two by coyotes, and one from internal parasites. Northern Harrier (*Circus cyaneus*), Great Horned Owl (*Bubo virginianus*), Red-tailed Hawk (*Buteo jamaicensis*), and coyote (*Canis latrans*) were identified as the main predators.

Reproductive Success. Between 1994–97, 28 young were produced from 12 nesting attempts (Table 2). Mean (SD) clutch size was 5.6 (2.1). Five of the 12 pairs that laid eggs failed to produce a brood. Failures were attributed to loss of one or both members of the pair as a result of predation or to inadequate forage availability. There were no instances where eggs were depredated. However, once an entire brood (N = 5) of 5-d-old nestlings was cannibalized by the female when the male failed to return. All chicks had been decapitated and their bodies partially consumed. The mean (SD) number of fledglings per successful pair was 4.1 (1.3). Females in three separate instances (data on re-nests not included in Table 2) re-nested after abandoning their first clutch, and one female re-nested after abandoning two clutches. Reasons for abandonment were unknown.

Dietary Habits. Prey data are presented for one release site, where an adequate number of pellets were collected. Owls were able to secure natural prey soon after release. Main prey items were meadow vole, deer mouse (*Peromyscus maniculatus*), northern pocket gopher (*Thomomys talpoides*), carrion beetle (*Silphidae*), several species of ground beetle (*Carabidae*), and spur-throated grasshopper (*Acrididae*). Prey remnants less frequently found in pellets included those of great basin spadefoot toad (*Scaphiopus intermontanus*), western toad (*Bufo boreas*), Western Meadowlark (*Sturnella neglecta*), Vesper Sparrow (*Pooecetes gramineus*), Mountain Bluebird (*Sialia currucoides*), and western terrestrial garter snake (*Thamnophis elegans*). The proportion of vertebrate remains in pellets was highest during

Table 2. Clutch size and number of fledglings observed per nesting attempt of released yearling Burrowing Owls. Dash indicates that no data were recorded.

Release Site	Year			
	1994	1995	1996	1997
Beresford	—	6 (3)	—	2 (0)
Lac du Bois	—	9 (5)	—	6 (0), 5 (2), 2 (0)
Long Lake	7 (4)	—	—	7 (0)
Guichon Ranch	9 (6)	5 (3)	9 (5)	5 (0)
Hamilton Commonage	—	—	—	—

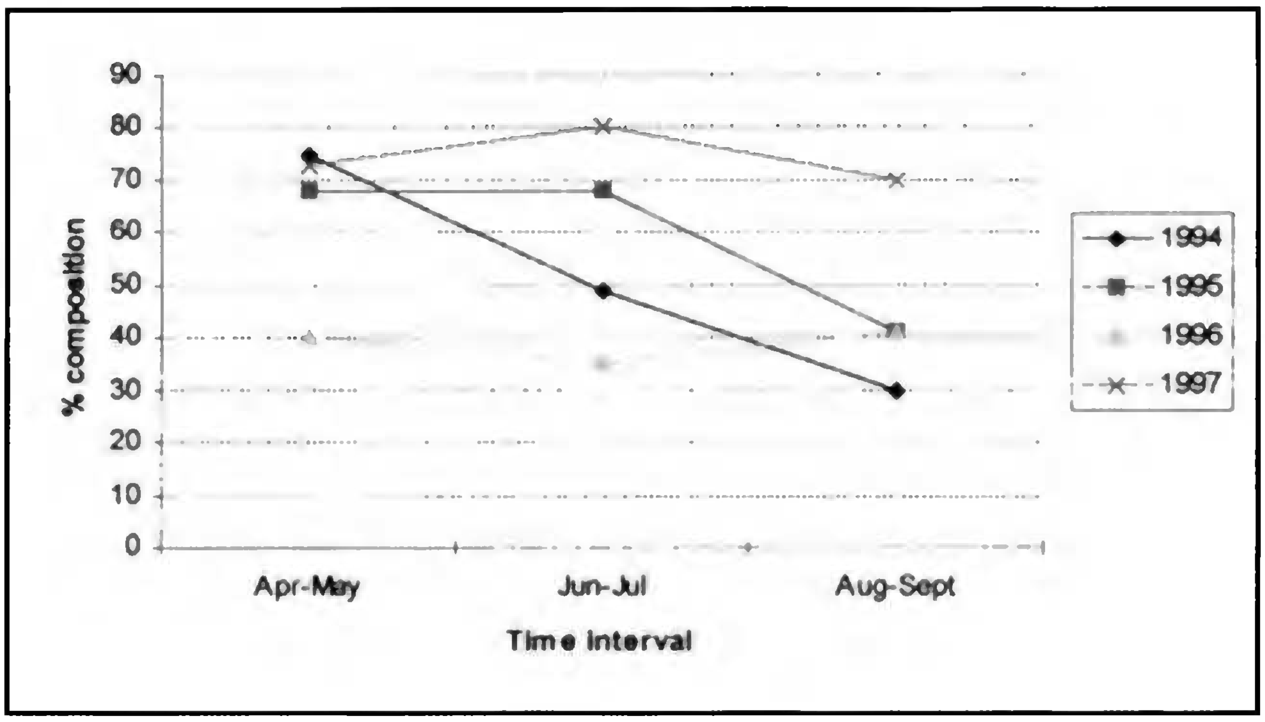

Figure 2. Percent vertebrate prey from pellets collected at Guichon Ranch, 1994–97.

April and May and gradually decreased as the seasons progressed (Fig. 2). In contrast, invertebrate prey was lowest during April–May and by September made up the bulk of the owl's diet (Fig. 3). Of the available insects, Burrowing Owls consumed coleopterans almost exclusively during the spring and early-summer and gradually shifted to grasshoppers as the season progressed.

Migration and Overwintering. Released owls rarely overwintered. Five of the 108 released owls remained at or near their release sites year-round, and two owls did so for three consecutive years. This behavior was observed only in males. In the winter, nest chambers contained as many as 23 stored rodents. Pellets ($N = 45$) collected for one owl in 1996 showed that meadow voles (56%) were the main prey items, followed by deer mice (28%), pocket gophers (10%), and orthopterans (6%). Despite temperatures <15°C, overwintering owls did not appear to be adversely affected by winter conditions. In fact, the mass of an owl recorded during its third winter at the Guichon Ranch release site in December was 260 g and a second one was 213 g when measured in February (the mean mass of a yearling owl at our facilities prior to release was 192 g). During these cool periods, nest

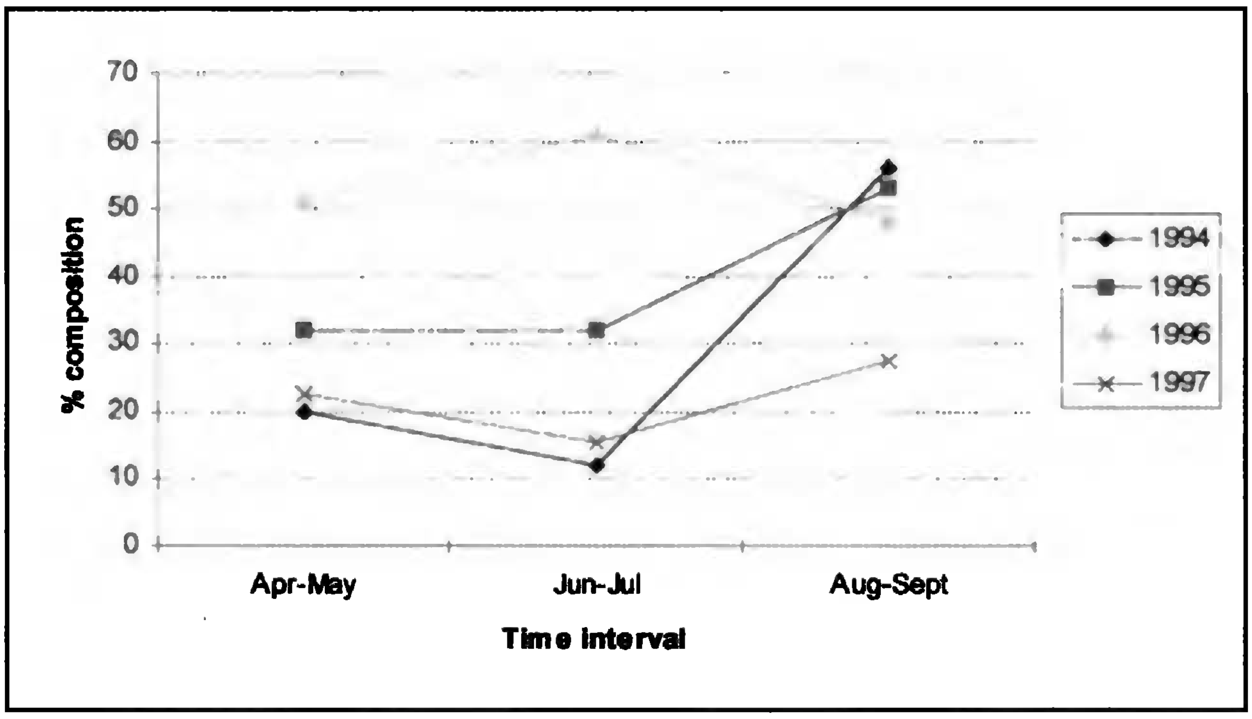

Figure 3. Percent invertebrate prey from pellets collected at Guichon Ranch, 1994–97.

chamber temperatures were near or slightly below 0°C. At this time, owls preyed exclusively on meadow voles and appeared to be active, except on days that temperatures dropped below −25°C or when burrow entrances where covered with excessive snow.

Most owls failed to return in spring after migration. Since 1993, only two released owls were known to return to their original release sites. In both instances, the returning owls were males that had been released in the previous year. The location of the owls' wintering grounds were unknown; however, a band from one released owl was recovered in Ephrata, Washington, in the winter of 1996.

DISCUSSION

Our results suggest that yearling captive-bred owls are able to secure natural prey and reproduce; they sometimes overwinter at release sites, or else migrate, and occasionally return to their breeding grounds the following year. These results are similar to those from other studies of captive-bred or transplanted Burrowing Owls elsewhere within their range in North America (De Smet 1997, Martell et al. 2001, L. Todd unpubl. data). Released owls in our study increased their consumption of invertebrates as the breeding season progressed, a behavior commonly reported for wild Burrowing Owls (Haug et al. 1993). Maser et al. (1971) and Grimm et al. (1985) have shown that this seasonal shift in food habits is a response to seasonal changes in prey availability. Brood sizes were within the range of brood sizes observed in a long-term study of wild owls in Alberta (Clayton 1997). Although infrequent, the few instances of owl returns, and the band recovery in Washington, suggest that captive-bred owls are capable of migrating and returning to original release sites. However, return rates were far lower than those observed in some wild populations. J. Schmutz, D. Wood, and G. Wood (unpubl. data) estimated that the return rate in a small sample of Burrowing Owls in Alberta was 44%. In Saskatchewan, James et al. (1997) reported annual return rates of 37–51%.

Mean mortality following release was high for captive-bred owls in all years. Mortality rates in 1997 were 20% lower than in 1996. In most years, releases were carried out soon after the onset of spring (between March–early-April), which happened to coincide with major hawk migrations. It appeared that delaying the releases to mid-April (Table 1) gave these 'naive' owls an opportunity to acclimate to the release sites and reduced their exposure to avian predators.

Our observations provide grounds for optimism about the eventual re-establishment of Burrowing Owl populations in BC. However, productivity and survival rates of the released owls are similar or lower to those observed in declining populations elsewhere in Canada (Wellicome and Haug 1995, De Smet 1997, Wellicome 1997). Therefore, our immediate efforts will focus on habitat management strategies in an attempt to improve productivity, increase the number of returning owls, and reduce mortality rates.

In a natural situation, the bulk of the Burrowing Owl's diet is made up of small mammals (E. Leupin and D. Low unpubl. data). Wellicome (2000) showed that supplemental feeding of pairs in Saskatchewan during the nestling period resulted in increased production of young compared to unfed pairs. Hence, increases in prey availability may increase owl productivity in BC. Current grazing regimes in BC provide little residual security cover for small mammals. Burrowing Owls prefer to nest in grazed areas with little vegetation (Coulombe 1971, Rich 1984), yet this habitat type is unsuitable for many small mammals. Small mammals, particularly meadow voles, are associated with riparian areas and dense cover (T. Dickinson, E. Leupin, V. Collins, M. Murphy unpubl. data). We intend to work closely with landowners to implement quick-rotation grazing strategies that create habitat heterogeneity and thus provide suitable habitat for Burrowing Owls and their primary prey species, such as the meadow vole that requires cover and fresh shoots of green grass (Jones 1990).

The breeding of owls at the two BC facilities has become finely-tuned over time; we now have the potential to produce almost 100 juveniles annually. This will allow us to conduct group releases of as many as 25 pairs at three separate release sites each year. We suggest that group releases will improve owl survival by increasing the number of individuals available to warn of approaching predators.

Finally, burrow availability has been cited as a key factor contributing to the decline of Burrowing Owls in BC (Howie 1980). The shortage of burrows has come about from a reduction in fossorial mammal populations. Currently, artificial burrows are placed in nesting and foraging habitats. Although artificial burrows are an effective short-term enhancement technique, they should not be considered an ultimate solution (Bryant 1990). Yellow-bellied marmot (*Marmota flaviventris*) and badger (*Taxidea taxus*) are two species that still persist in BC's grasslands. In future years, we will concentrate in restoring populations of these burrowing mammals, which should in turn provide a natural source of burrows for the owl.

ACKNOWLEDGMENTS

Funding for this project was provided by the Habitat Conservation Trust Fund. Additional funding was kindly provided by the following organizations: Trans Mountain Pipeline Ltd., Shell Environmental Fund, Petro Canada, Fredrick Metcalf Charitable Foundation, Imperial Oil, Canada Trust Friends of the Environment Foundation, and Molson Industries. We owe a great deal of gratitude to all volunteers and landowners, for without their support and involvement, this project would not have been possible. The British Columbia Conservation Foundation provided administrative support and aided with fundraising. All fieldwork would not have been possible without the efforts of the people at the captive-breeding facilities and education programs; we would like to thank Dawn Brodie, Mike Macintosh, Bill Gilroy, the Kamloops Wildlife Park, and the Stanley Park Ecology Society for their efforts. Finally, we thank Myke Chutter, bird specialist in Victoria, for valuable comments on an earlier version of this manuscript and also J. Barclay, M. Martell, and an anonymous reviewer for their thoughtful suggestions.

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CONSERVATION OF THE BURROWING OWL IN WESTERN NORTH AMERICA: ISSUES, CHALLENGES, AND RECOMMENDATIONS

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ABSTRACT.—Burrowing Owls (*Athene cunicularia*) are undergoing mild to relatively severe local and regional population declines throughout much of western North America. In Canada, Burrowing Owls are declining precipitously and are listed as endangered. In the United States of America, Burrowing Owls continue to decline in many states, but they are not listed federally. In Mexico, there is little quantitative data, but the species is listed as threatened. Here, we propose a conservation plan with five major action components: status, management and conservation, education, research, and administration. Given continued declines of Burrowing Owls in many parts of western North America, we urge increased cooperation among interested agencies and organizations to implement effective conservation of this species.

KEY WORDS: *Burrowing Owl;* Athene cunicularia; *conservation; population decline; status; sciurid; international cooperation; Canada; Mexico; United States of America; North America.*

Conservación del Búho Cavador en el occidente de Norte America: tareas, retos, y recomendaciones

RESUMEN.—Los Búhos Cavadores (*Athene cunicularia*) han experimentado a nivel local y regional un declive moderado a relativamente severo de sus poblaciones en la mayoría del oeste de Norte América. En Canadá, los Búhos Cavadores están declinando precipitadamente y son considerados como una especie en peligro. En los Estados Unidos de América, los Búhos Cavadores continúan declinando en muchos estados, pero no están en ningún listado a nivel federal. En México, hay muy pocos datos cuantitativos, pero aun asi la especie es listada como bajo amenaza. En este articulo, nosotros proponemos un plan de conservación con cinco grandes componentes: estado, manejo y conservación, educación, investigación y administración. Dado el continuo declive de los Búhos Cavadores en muchas partes del oeste de Norte América, nosotros hacemos un llamado urgente para incrementar la cooperación entre las agencias interesadas y las organizaciones para implementar una conservación efectiva de esta especie.

[Traducción de Victor Vanegas y César Márquez]

During the second international Burrowing Owl symposium (29–30 September 1998 in Ogden, Utah), participants presented papers on the status of the western Burrowing Owl (*Athene cunicularia hypugaea)* in many states and provinces of the United States (U.S.), Mexico, and Canada. Papers were also presented on aspects of the owl's biology, management, and conservation. The objectives of this paper are to summarize conservation issues that affect the western Burrowing Owl and its habitats, and to recommend possible solutions. These recommendations include international coordination and cooperation, standardized monitoring, education, policy change, management and conservation, and research.

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This paper integrates ideas from several papers included in the symposium and synthesizes open discussion from the final session of the symposium. These papers, and the discussion, focused on the status and conservation needs of the Burrowing Owl in the three countries of North America. At the final session, symposium attendees agreed that the western Burrowing Owl is declining over most of its range in North America. They based this conclusion on information provided in 34 oral presentations included in the symposium. Articles based on many of these presentations, plus a few others, are included in this volume of the *Journal of Raptor Research.*

Attendees at the symposium's final session contributed to this proposed conservation plan, which was further reviewed and refined in early 2001. The intended audience for this plan is all wildlife managers in western North America, but particularly the wildlife and land management agencies in Mexico, U.S., and Canada, within the range of the western Burrowing Owl (Wellicome and Holroyd 2001). The goals of this conservation plan are: 1) to encourage land-use practices that reverse the population decline of the western Burrowing Owl; 2) to determine what factors, not related to habitat modification, may also contribute to the species' decline; and 3) to help conserve the ecological integrity of grasslands in western North America. These goals can be achieved through conservation action and improved cooperation among wildlife agencies, land managers, and the public in these three countries.

The western Burrowing Owl inhabits grassland ecosystems of midwestern and western North America. These ecosystems have been greatly modified by human perturbations (Samson and Knopf 1996). Overall, <25% of the original grasslands remains as native vegetation in Canada and the U.S., but in some states and provinces as little as 1% remains (World Wildlife Fund Canada 1988, Samson and Knopf 1996). In Mexico, 12% of the land area was dominated by grasslands that were mainly distributed in the northern part of the country (Sonora, Chihuahua, Durango, Coahuila, Nuevo Leon, Zacatecas, Aguascalientes, and Jalisco; Rzedowski 1978). Grassland patches in Mexico originally were distributed widely throughout several ecosystem types, though most grassland has since disappeared because of human activities. Grasslands in Mexico are used intensively by the livestock industry (Miller et al. 1994).

In the U.S., Burrowing Owls have experienced both local and regional population declines (Sheffield 1997a). In 1972, the Burrowing Owl was included on the Audubon Blue List, a list intended to provide an early warning about North American bird species undergoing population or range reductions (Tate 1986). In the U.S., the Burrowing Owl has been designated as vulnerable (U.S. Department of Interior 1991), sensitive (U.S. Department of Interior 1992), federal category 2 candidate species per listing under the Endangered Species Act, and declining (White 1994). The federal category 2 candidate species classification was officially dropped by the U.S. Fish and Wildlife Service (USFWS) in late 1996 (published in the 5 December 1996 Federal Register). Currently, the Burrowing Owl has no federal regulatory designation in the U.S., but is included as a national priority species by the USFWS in their most recent Birds of Conservation Concern 2001 list (U.S. Fish and Wildlife Service 2001). The owl is listed as a national conservation priority species, and also listed as a regional conservation priority species in USFWS Regions 1, 2, and 6, which includes midwestern and western U.S. A status assessment of the western Burrowing Owl in the United States is being prepared currently (S. Jones and L. Ayers pers. comm.).

In Canada, the Committee on the Status of Endangered Species in Canada (COSEWIC) classified this species as threatened in 1979 (Wedgwood 1978), confirmed it as threatened in 1991 (Haug and Didiuk 1991), and changed its designation to endangered in 1995 (Wellicome and Haug 1995). Burrowing Owls were extirpated from British Columbia in the 1970s (Wedgwood 1978) and from Manitoba in 1998 (K. De Smet pers. comm.). Range contraction and population declines have been particularly acute in Canada (Wellicome and Holroyd 2001). Numbers declined by an average of 20% per yr in Alberta (1991–2000, Operation Burrowing Owl [OBO] Alberta publ. comm.), 21.5% per yr in Saskatchewan (1988–2000, OBO Saskatchewan, Skeel et al. 2001), and 25% per yr in Manitoba (1987–98, De Smet 1997). A national recovery team has met annually since 1989, and a Canadian recovery plan was published in 1995 (Hjertaas et al. 1995).

In Mexico, the Burrowing Owl was listed as a federally threatened (amenazada) species in 1994 (Diario Oficial de la Federación 1994). The Burrowing Owl is widely distributed in Mexico (Wellicome and Holroyd 2001), especially in northern arid regions, and is common at a few locations (Haug et al. 1993, Enriquez-Rocha 1997, R. Rodriguez-Estrella and G. Holroyd unpubl. data). Enriquez-Rocha et al. (1993) and Enriquez-Rocha (1997) analyzed 279 records of Burrowing Owl specimens from 27 museums (6 Mexican, 21 foreign) and found that Burrowing Owls were distributed widely, and located in 28 of 32 Mexican states. There is virtually no published information on population estimates or trends of resident or migrant Burrowing Owls in Mexico (R. Rodriguez-Estrella pers. comm.). Most reports in Mexico are anecdotal, mainly distributional records, with only a few referring to its ecology (Clark et al. 1997). Since the 1992 International Burrowing Owl Symposium (Lincer and Steenhof 1997), only four papers have been published on this owl in Mexico, two of which were published in the proceedings of that meeting (Enriquez-Rocha 1997, Rodríguez-Estrella 1997); of the other two, one was a general review of owls in Mexico (Enriquez-Rocha et al. 1993) and the other was specific to owls in Baja California (Palacios et al. 2000). Without information on the number and trends of owls, there is no way to determine quantitatively the current status of resident and wintering populations of the Burrowing Owl in Mexico.

In North America, the Burrowing Owl is protected by national and state/provincial laws. In the U.S. and Mexico it is protected under national laws that enact the Migratory Bird Treaty of 1972. The Burrowing Owl has some form of special status in 12 states (James and Espie 1997). The Canadian–U.S. Migratory Bird Convention (1916) does not include Burrowing Owls or other raptors. Therefore, in Canada, it is protected under provincial wildlife acts in the four western provinces where the species occurred historically. In addition, Burrowing Owl is listed by The Convention on International Trade in Endangered Species (CITES) in Appendix 2, which makes it illegal to possess or trade this species (including any body parts). The Burrowing Owl is classified as a neotropical migrant by Partners in Flight.

Several issues and threats are responsible for the current plight of the Burrowing Owl in North America (Haug et al. 1993, Lincer and Steenhof 1997). Burrowing Owls are faced with an ever-changing landscape, and less and less suitable habitat. Ecologically, they are often associated with fossorial (digging) species of mammals (e.g., prairie dogs [*Cynomys* spp.], ground squirrels [*Spermophilus* spp.], and badger [*Taxidea taxus*]), which are all commonly eradicated by humans. Prairie dog populations continue to decline because of sylvatic plague and eradication programs (Bishop and Culbertson 1976, American Society of Mammalogists 1998). Ground squirrels also are eradicated in many grassland regions. Pesticides used extensively on grasslands inhabited by Burrowing Owls cause both direct and indirect mortality (Sheffield 1997b). Burrowing Owls continue to lose suitable habitat and are killed by human activities, and they often fledge far fewer young than their reproductive potential would allow (Wellicome 2000). The challenge that we face is how to best manage all of the problems facing the Burrowing Owl, so we can ensure that grasslands of the future will include this unique species.

After the First International Burrowing Owl Symposium, Lincer (1997) summarized 11 issues and needs identified as important to the conservation and management of the Burrowing Owl. All of these issues, and others, were discussed at the Second Symposium and incorporated into this paper. In this paper, we have organized conservation issues that affect the Burrowing Owl into five categories: status, management and conservation, education, research, and administration. In some cases, we have been able to provide an update on actions undertaken to mid-2001.

Population Status and Distribution

The status of the western Burrowing Owl in North America has not been assessed adequately, and no standardized survey data exist for this species across its range. In Canada, Burrowing Owls have been extirpated in British Columbia (Wedgwood 1978) and Manitoba (K. De Smet pers. comm.). They still breed in southern Alberta and Saskatchewan, but their range has contracted from the north and east (Wellicome and Holroyd 2001). In the U.S., Burrowing Owls occurred from western Minnesota and Iowa south to northern Texas and west from California to Washington. However, their range has been reduced, particularly in the east (Haug et al. 1993, Wellicome and Holroyd 2001). They no longer occur in Minnesota, Iowa, the eastern parts of the Dakotas, south to central Oklahoma (Haug et al. 1993, Wellicome and Holroyd 2001, Sauer et al. 2000, Sheffield and Howry 2001). According to Breeding Bird Surveys (BBS), the number of Burrowing Owls have declined in the Great Plains at over 1.5% per yr from 1966 to 1996 (Sauer et al. 2000). In Mexico, Burrowing Owls breed from Aguascalientes north between the Sierra Madre Oriental and Occidental, and in Baja California and parts of Sonora, but little is known about their breeding population status or their range and status in winter (Enriquez-Rocha et al. 1993, Enriquez-Rocha 1997).

During the symposium, historical and current data on Burrowing Owl abundance and distribution were presented. However, much of the information was qualitative and none of it was standardized among jurisdictions. The North American BBS shows a non-significant decline (3.8% per yr) in the central BBS region and a significant decline of 12% per yr in Canada but detection rates are low (0.63 and 0.05 owls per route, respectively, Sauer et al. 2000). In the western BBS region the number of owls increased by 4.8% per yr (P = 0.03) although again the number of detections are low (0.44 owls per route).

Status Action Items

(1) Determine the status of the Burrowing Owl in the U.S. using existing information. A status assessment of the western Burrowing Owl in the United States is being prepared (S. Jones and L. Ayers pers. comm.).
(2) Undertake a standardized survey for western Burrowing Owls in North America to establish a quantitative baseline for future assessments of overall population trends. For example, recent surveys of prairie dogs have identified 1000s of colonies in the Great Plains from the Dakotas to Texas. Burrowing Owls should be surveyed and regularly monitored on these colonies.
(3) Test survey protocols for nesting Burrowing Owls in a variety of habitats so that the continental survey follows prescribed quantitative techniques.
(4) Compile historical information on Burrowing Owls, prairie dogs, and other fossorial mammals in western North America.

MANAGEMENT ACTIVITIES

Grassland habitats are managed directly and indirectly on private and public lands, but the needs of Burrowing Owls are seldom considered. On public lands, managers should consider the needs of Burrowing Owls in their land-use planning and operations. Environmental assessment of developments, pesticide applications, grazing regimes, and other human activities should be evaluated to determine their effect on Burrowing Owls.

Information is lacking on the effects of human activity and human-dominated environments on the biology and habitat use of Burrowing Owls. Some Burrowing Owls may take advantage of areas containing crop fields and orchards, particularly migrant species in their wintering areas, to exploit abundant food sources (i.e., insects and rodents; Rodríguez-Estrella et al. 1998). However, intensive cultivation of grasslands and native prairies is a suggested cause of declines in populations of breeding owls (Haug et al. 1993).

Ideally, conservation programs for Burrowing Owls include landowner stewardship on both private and public lands. In Saskatchewan and Alberta, >750 landowners voluntarily protect 100 000 ha of prime nesting habitat through stewardship programs called Operation Burrowing Owl (Skeel et al. 2001). Rocky Mountain Bird Observatory also has launched the Prairie Partners program for stewardship of grassland habitat to conserve the Burrowing Owl and other grassland species in Colorado, Wyoming, Montana, and New Mexico (VerCauteren et al. 2001). Because Burrowing Owls nest in burrows of prairie dogs, ground squirrels, and other fossorial mammals, the owls' future is tied to the conservation of these mammals and their native habitats.

To date, translocations of Burrowing Owls have met with some success (Delevoryas 1997, Feeney 1997, Schultz 1997), but re-establishment of populations has been unsuccessful in Manitoba (De Smet 1997), B.C. (Leupin and Low 2001), Minnesota (Martell et al. 2001), and Saskatchewan (L. Todd unpubl. data).

Management Action Items

(1) Determine habitats used by Burrowing Owls, map the distribution of these habitats throughout western North America, and determine threats to these habitats.
(2) Develop and standardize mitigation protocols for developments and disturbances, such as airports and oil and gas developments, to minimize impacts on Burrowing Owls. Standardized assessment guidelines for the petroleum industries' impacts on Burrowing Owls and other prairie species of special concern in Canada were recommended by Scobie and

Faminow (2000) and could be used as a template for further work.

(3) Include Burrowing Owl issues in land management plans for public lands, Environmental Impact Statements for National Grasslands (U.S.), and Management Plans for National Parks and Prairie Farm Rehabilitation Agency lands (Canada). The Burrowing Owl should be included in Habitat Conservation Plans and in the Candidate Conservation Agreement with Assurances program for black-tailed prairie dogs in the U.S.

(4) Review Burrowing Owl reintroduction techniques, and develop new techniques because reintroduction programs in four jurisdictions have not been successful.

(5) Manage rangelands to enhance productivity and survival of the owls, their prey, and fossorial mammals.

(6) Summarize design and installation techniques for artificial nest burrows for the Burrowing Owl and review their efficacy. In 1999, Saskatchewan Environment and Resource Management printed a booklet on this topic (Poulin 1999). The conservation value of artificial burrows also should be determined.

(7) Conduct follow-up research to determine the breeding success of translocated Burrowing Owls and, ultimately, to develop effective translocation techniques.

(8) Identify and conserve wintering habitats for Burrowing Owls. Owls are known to winter in south Texas, Gulf coast lowlands and central Mexico, southern California, Baja, and local areas in northern Mexico and adjacent U.S., but little is known about habitat use during winter.

(9) Ensure pesticides have no negative effects on Burrowing Owls on both breeding and wintering grounds.

(10) In the U.S. and Mexico, implement voluntary land-stewardship and management programs like Operation Burrowing Owl and Prairie Partners.

(11) Promote stewardship of Burrowing Owls and their habitat on all government lands within the owls' range in all three countries. A coordinated effort is needed by federal agencies to promote and to manage biodiversity in native grasslands.

(12) Review government programs and policies to ensure that land-use changes have a positive effect on the conservation of Burrowing Owls, their habitats, and associated wildlife, such as fossorial mammals.

(13) Conserve prairie dogs, ground squirrels, and badgers to provide nesting burrows and habitat for owls. Prairie dog colonies should be expanded substantially on public lands. Land-use practices and legislation should make it profitable and beneficial to maintain and to conserve prairie dog populations on private lands. Federal, state, and locally-supported control programs should be re-evaluated to ensure that adequate populations of prairie dogs and ground squirrels remain to support all species associated with this ecosystem.

EDUCATION

Burrowing Owl conservation depends on the attitudes of grassland landowners, land managers, and society in general. A change of philosophy with regard to prairie dogs, ground squirrels, and grasslands is required. Some sectors of society view grasslands as non-productive, easily-developed, weedy, or problem areas; whereas, they should be conserved as an integral part of natural, functioning ecosystems, and as the basis for a sustainable economy. We will have to work hard to change the negative image of prairie dogs and ground squirrels. Educational materials that promote broader prairie conservation issues, including Burrowing Owl conservation needs, should be developed and distributed to land managers and schools. The Burrowing Owl can be used to encourage land stewardship that benefits other grassland wildlife.

Education Action Items

(1) Use the Burrowing Owl as a flagship species to promote broader prairie conservation issues. Education programs in the U.S., Canada, and Mexico could include teaching the value of native grasslands and their components (e.g., Burrowing Owls, prairie dogs, insects, grasses).

(2) Develop specific educational material for school curricula, such as Alberta's Burrowing Owl teachers' guide (Alberta Environmental Protection, 1995, Edmonton, Alberta, Canada).

(3) Promote the conservation of the Burrowing Owl and other grassland wildlife through newspapers, magazines, and other media.

Where possible, local people should be involved in Burrowing Owl research. Research results should be reported in local media.

(4) Develop prairie conservation literature specifically for landowners. Environment Canada, Rocky Mountain Bird Observatory, and others have produced landowner booklets that can be used immediately (Holroyd et al. 1995). Grassland habitat displays should be included in regional, agricultural, and nature interpretive centers.

(5) Use non-releasable Burrowing Owls and captive-bred, imprinted owls for educational programs where possible.

(6) Use the Internet to educate the public about Burrowing Owls, fossorial mammals, and grassland wildlife conservation (e.g., provide lesson plans, Burrowing Owl web pages, research results).

RESEARCH

Causes of the decline of the western Burrowing Owl are not fully known. Research is needed to determine causes so that management actions can be targeted and implemented to reverse the decline. In Canada, research has shown that productivity is low and mortality is high, but little is known about the extent of dispersal or emigration of owls into various parts of Canada and the U.S.

Research Action Items

(1) Study the population demographics of Burrowing Owls in the U.S. and Mexico to compare to existing Canadian data and to help determine causes of declines.

(2) Conduct population modeling that incorporates existing demographic data to determine gaps in our knowledge and possible causes of the decline.

(3) Determine annual site fidelity of migratory adult and juvenile owls. Accurate population modeling requires separation of emigration from annual mortality.

(4) Determine the effect of predation (from both natural and feral predators) and other sources of mortality on Burrowing Owl populations and establish how these factors contribute to population declines.

(5) Model Burrowing Owl habitat-use and habitat-selection, including human-related factors, to understand the role of human activity (i.e., agriculture, urbanization) in population declines.

(6) Conduct research on the distribution, survival, and threats to wintering owls.

(7) Determine routes, habitat needs, and survival of migrating owls, because little is known about this part of the annual cycle.

(8) Study the effects of pesticides on owls and their food in both summer and winter in all three countries.

(9) Evaluate the effects of grazing systems, fire, and other land uses on Burrowing Owls, their prey, and habitats.

(10) Conduct social science research to examine and to improve landowners attitudes toward burrowing mammals.

ADMINISTRATION

Official international agreements are needed to establish functional, cooperative programs between government agencies, universities, and research centers of the three countries included in the North American Free Trade Agreement. Common strategies of natural resource management and conservation should be developed and supported jointly by each national agency. In 1996, the federal wildlife agencies of the United States, Mexico, and Canada established the Canada/Mexico/U.S. Trilateral Committee for Wildlife and Ecosystem Conservation and Management (Trilateral). The Trilateral Committee facilitates and enhances cooperation and coordination among the countries' wildlife agencies in programs for the conservation and management of wildlife, plants, biological diversity, and ecosystems of mutual interest. In 1997, the Trilateral established a Burrowing Owl Working Group comprised of one representative per country to determine the conservation needs of this species. The Ogden Symposium and this paper were organized on this group's behalf. Some of the issues identified in this paper were included in the Commission for Environmental Cooperation's "Species of Common Conservation Concern in North America" (unpubl. draft 2000, Montreal).

Administrative Action Items

(1) Present the recommendations from the Burrowing Owl Symposium at the Trilateral Meeting. This was done at the 2000 Trilateral meeting in Padre Island, Texas, and updated at the 2001 meeting in Ottawa, Ontario.

(2) Promote greater international cooperation be-

tween the three countries to conserve Burrowing Owls. A North American Burrowing Owl Conservation Program should be initiated as a joint effort between the U.S., Canada, and Mexico.

(3) A list serve was established to enhance communication among Burrowing Owl conservationists. To subscribe send the following message to *listserv@unl.edu* with "subscribe burrowingowl *your name*" in the message and leave the subject line blank.

(4) Update the Burrowing Owl bibliography of Clark et al. (1997) that has been made available, with additions, on the web (http://uwadmnweb.uwyo.edu/fish_wild/buow/index.html).

(5) Strengthen links with other grassland researchers and scientific societies concerned with grassland habitat and its components. The resolution of the American Society of Mammalogists (1998) regarding conservation of prairie dogs and their habitat was endorsed by the Burrowing Owl Symposium attendees.

(6) Provide up-to-date information on Burrowing Owls to international bird conservation programs, such as Partners in Flight and the North American Bird Conservation Initiative, to support the conservation ranking of this species as high priority.

(7) Organize another symposium in 2001 in conjunction with the annual meeting of the Raptor Research Foundation, Inc., in New Orleans.

Conclusions

Burrowing Owls continue to undergo mild to severe local and regional population declines throughout much of their range in North America. Habitat destruction and alteration has played a major role in the decline of the Burrowing Owl. Increased mammalian predation, pesticide use, and other human-related mortality factors also may have contributed. Prairie dogs and ground squirrels continue to be exterminated in many areas of North America, and prairie grasslands continue to be converted for crop farming and other uses. Livestock production on grasslands often does not provide for conservation of native habitats and wildlife. Species such as Burrowing Owls and prairie dogs serve as important sentinels of the overall health of grassland ecosystems in North America, and currently they are telling us that our native grasslands are degraded in many areas. Proactive conservation measures, education, and changes in public attitudes and policy are necessary for the maintenance of viable populations of Burrowing Owls and grassland sciurids in North America. Integrated efforts to conserve native grassland habitats, and hence Burrowing Owls, should involve researchers, federal, state, and local governments, non-governmental organizations, and interested private citizens from all three North American countries.

Acknowledgments

We thank J. Belthoff, D. Flath, R.K. Murphy, H. Trefry and T.I. Wellicome for interesting discussions on Burrowing Owls, and L. Ayers, J. Bednarz, J. Hoth, S.L. Jones, D.J. Krueper, J.L. Lincer, R. List, R. Mesta, D. Rosenberg, J. Sidle, K. Steenhof, D. Stepnisky, T.I. Wellicome, and H.E. Trefry for helpful comments on the manuscript Centro de Investigaciones Biológicas del Noroeste and CONACyT (México; 31372-N) supported the work of R Rodríguez-Estrella.

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